Integrating Land and Water Management: A Suburban Case Study and User-Friendly, Locally Adaptable Tool

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BACKGROUND AND PURPOSE

Managing the impacts of growth and development on California's water resources is an ongoing challenge. The California Department of Water Resources (DWR) approved a Land Use Resource Management Strategy in 2009 that called for Low Impact Development (LID) and Leadership In Environmental and Energy Design (LEED) strategies to reduce land use impacts on water supply benefits. The Resource Management Strategy also set in motion a study to quantify costs and benefits associated with water-smart land use practices. The main purpose of the tool is to enable the local decision makers—planners, developers, officials—to understand choices and consequences, especially for long-term costs affecting water supply and quality, storm water management, and energy use. This report describes the use of the 2009 decision tool of the California

PROJECT DESCRIPTION

Sonoma State University's Center for Sustainable Communities was contracted by DWR to co-produce an evidence-based report and a user-friendly tool capable of calculating water related benefits and costs associated with local land development. This report includes case studies of four suburban development projects located in central Sonoma County. These development projects consist of: detached single-family subdivisions that predate contemporary urban stormwater standards; projects that meet such requirements; and designs that incorporate a variety of LID, LEED and other sustainable development standards. The case studies are compared and contrasted to one another with a new *Integrated Water and Land Smart Planning Tool*.

ANALYSIS AND CONCLUSIONS

This project was initiated as a result of the vision and leadership of the DWR Project Director. Early on, the project team surveyed existing tools that quantify various water supply benefits. Although existing tools (including guides, reports and calculators) are available to guide practitioners, often tools that were easy to use could not be modified to reflect local conditions, while calculators that could be modified possessed challenging user interfaces that required extensive background knowledge. Consequently, the project team determined that a user-friendly calculator with the ability to customize and save local data would be a valuable asset for city, county and regional officials, agency staff, home owners, and local developers. After analyzing four Sonoma County case studies with the tool, we found that projects with reduced hardscapes and smaller building footprints are likely to yield the most economical designs while minimizing impacts on water quality, flooding, and water supply reliability.

NEXT STEPS

1. Distribute and test the "Integrated Water and Land Smart Planning Tool at local planning, building and public works departments.
2. Conduct case studies of higher density residential and mixed-use urban projects.
3. Revise and update the "Integrated Water and Land Smart Planning Tool" to reflect the above.

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1 INTRODUCTION

Local land use decision makers have few user friendly tools by which to measure and assess project location and design choices. While state agencies recognize that land use decisions are made by local jurisdictions, the California Department of Water Resources, in furtherance of state policies for land use and water supply and quality benefits, contracted with Sonoma Sonoma State University's Center for Sustainable Communities to develop test and test a tool in a pilot project. The tool is designed for local decision makers considering land use and project design decisions based on economic development needs and consistency with general and specific plans.

1.1 BACKGROUND

As California's population and development footprint continues to grow, managing impacts on water resources is an ongoing challenge. The most common pattern of growth—post-World War II style, low-density residential development—is widely agreed to be too resource intensive to accommodate future residents CITE. To support more efficient growth, the California Legislature has adopted policies and programs to better integrate land use and resource management.[1] Although land use standards are still limited, the need for a shift in land use strategies is becoming a noticed reality.

In 2009, the Land Use Resource Management Strategy (RMS) [IMAGE 1.1] called for Low Impact Development (LID) and LEED strategies to reduce land use impacts on water supply benefits. LID and [IMAGE 1.2] LEED strategies are suggested in order to:

- Decrease household water consumption
- Increase quality of stormwater runoff
- Decrease volumes of stormwater runoff
- Decrease rates of stormwater runoff
- Decrease downstream flood risks

The 2009 Land Use RMS set in motion a study to quantify costs and benefits associated with water-smart land use practices. Following the 2009 initiative, the charter for the Land Use Planning and Management RMS in the 2013 Plan update proposed the creation of a land use decision tool and demonstration of its application through pilot projects. To execute this study, the State of California's Department of Water Resources partnered with Sonoma State University's Center for Sustainable Communities (SSU). This report introduces the new Integrated Water Management and Land Use Planning tool created by DWR and SSU. [IMAGE 1.3]

[1] "This resource management strategy is consistent with the following: State goals for more compact sustainable development (State Assembly and Senate bills AB 857, SB 732 and SB 375); regional blueprint planning being funded by California Department of Transportation (Caltrans); strategies being developed by the California Air Resources Board (ARB) to achieve AB 32 greenhouse gas (GHG) reduction target; and SB 375 linking land use and transportation" (California State Water Plan 2009, Chapter 24)

1.2 STUDY OBJECTIVES

Following recent trends to integrate water and land use, there is an increasing need to quantify the benefits and costs of land use and land cover choices. Many commonly used methods of assessing benefits and costs do not adequately address lifecycle costs, positive and negative externalities, and non-monetary impacts. This study seeks to relate local land use and land cover choices to a comprehensive set of benefits and costs over time and space, identifying both immediate and cumulative impacts.

To do so, SSU built a tool which allows users to input different residential land cover and infrastructure choices and compare development scenarios. [IMAGE 1.4] Principles guiding the study and creation of the tool are as follows:

- Create an open, locally-modifiable and user-friendly tool to help guide land use and land cover decisions
- Quantify relationships between land use alternatives and key water supply benefits, including water supply reliability, flood management, water quality, habitat value, Climate Action Mitigation
- Quantify the monetary costs of implementing LID and traditional development strategies, including long term costs
- Compare and contrast different development styles exemplified in four case study sites

1.3 WORKING WITH THE TOOL

To make the tool as transparent and accessible as possible, we chose to implement it in Microsoft Excel. [IMAGE 1.5] The tool is available for download and can be used by anyone running Excel (PROVIDE LINK). Within the Excel spreadsheet, all the calculations and data are visible and editable. Users are invited to view, critique, and change the tool to reflect local policies, practices, services and emerging information. [IMAGE 1.6] Further information on working with the tool is available via the User Guide.

➤ FUTURE USERS

While the tool is primarily to address the relationship between water and land at the lot and neighborhood (e.g., Planned Unit Development) scale, it is also possible to scale up the results of the tool to the city, region, and watershed. Because of the range of spatial scales which the tool addresses, the results will apply to a broad user base. These users may include:

- Home owners
- Project developers
- Elected and appointed decision-makers, such as council members, and planning commissioners and supporting staff members
- Regional agencies
- Researchers

Homeowners may be interested in testing possible retrofits to their properties, examining costs versus benefits. Residential developers may be interested in evaluating design strategies to propose for new projects. Public agencies and researchers may employ the model to envision cumulative impacts of development strategies on broader spatial scales or evaluate alternative futures.

In developing this tool we also anticipated that it would be a useful component for city and county agencies reviewing development proposals and addressing the relationship between land use, water quality and water consumption. By developing quantifiable comparisons of project alternatives, agency staff and decision-makers can evaluate the effectiveness of conservation measures being considered for inclusion in a project, either through suggested redesign or conditioning. Local agencies may also find the model a useful tool for generating standards that would apply to new development through general plan policies, zoning regulations, design guidelines or other planning documents designed to give guidance to private project proponents.

➤ INPUTS

Within the tool, the user selects the tab for their spatial scale of interest. For example, a home owner might select the "Lot" tab. On the Lot tab the homeowner inputs the land covers on the lot (in square feet) and information on water infrastructure (e.g., "Is there an irrigation controller?"). [TOOL IMAGES]

➤ OUTPUTS

From the Inputs, the tool calculates 7 metrics: 4 metrics which relate to water supply benefits and 3 which relate to upfront and long term monetary costs. These costs are discussed in further detail in Section 2.3.

Water Metrics

1. Percent impervious surfaces [IMAGE 1.7]
2. Stormwater runoff (from impervious surfaces)
3. Outdoor water requirements
4. Greenhouse gas emissions (from applied outdoor water) [IMAGE 1.8]

Monetary Metrics

1. Cost of implementation
2. Cost over 50 years
3. Cost over 100 years [IMAGE 1.9]

The metrics are calculated with the highest degree of accuracy at the lot and neighborhood level.

1.4 CASE STUDIES

Four pilot projects in Sonoma County were used to test and calibrate the model:

1. A traditional[2] single-family detached subdivision predating stormwater policies and not explicitly incorporating LID or LEED measures;
2. A subdivision with some meeting the local Standard Urban Stormwater Mitigation Plan (SUSMP) and implementing some LID strategies;
3. A subdivision with many LID and LEED strategies which exceeds SUSMP and earned a GreenPoint certification;
4. A projected development designed with water conservation and quality as major components meeting One Planet objectives.

We chose to focus this study in Sonoma County because many of the developments are representative of suburban, residential areas throughout the state. Yet, Sonoma County is also home to many developments implemented under more progressive water standards. [IMAGE 1.10] With Traditional, SUSMP, GreenPoint and One Planet case studies, we anticipated the range a wide spectrum of outputs from the tool.

Because of the case studies are located within Sonoma County, the tool is specified with data from Sonoma County. The costs and figures were primarily gathered from Sonoma-based sources. Differences in microclimates, labor costs, and local behavior will impact the accuracy of the tool in other areas. [IMAGE 1.11] Though some data may be transferrable, we suggest that number and formulas be reviewed and updated with information that is as locally-specific as possible.

[2] For the purposes of this study, the single family homes of the post World War II, mid 20th century era, as "traditional."

1.5 FINDINGS

A selection of the findings developed further in this paper are as follows:

- There are few user-friendly tools which test and compare Low Impact Development scenarios
- An easy to use water smart calculator fills an important gap, provided it is designed to be transparent, accessible, modifiable, scalable and comprehensive
- Projects with reduced hardscapes, smaller building footprints and less elaborate infrastructure requirements are more likely to yield the most economical designs.
- Since the benefits of green infrastructure often accrue over the long term, not at implementation, the incentive for developers to explore alternative infrastructure options is low. Further developing full cost metrics may help reveal the urgency of managing lifecycle costs at the initiation of a project.
- Mitigating is not as effective as avoiding new impervious surfaces. For example, resizing stormwater pipes in conjunction with upstream green infrastructure has the potential for measurable cost and energy savings
- This tool enables people without technical backgrounds to more easily assess and understand the relative impacts of different development choices and the cumulative impacts of small choices.
- The energy required for supplying and treating water and wastewater represent the largest municipal energy costs. The impacts of a "business as usual " approach may be magnified over time for water supply, treatment (waste and storm) and rate payer costs
- The closer development is to the water source, the less wastewater has to be conveyed and treated. This reduces energy use and GHG emissions.
- Maintenance costs are not well documented because the initial developer who purchases and constructs the facilities is often not responsible for long-term maintenance. Dividing up those full costs into who bears the cost may help reveal how short-term cost savings at the lot or neighborhood level lead to onerous, long term expenses carried by the municipality.
- Green infrastructure was difficult to value as it is challenging to accurately gauge lifecycle costs. Nevertheless, green infrastructure in lieu of grey infrastructure has the potentially to substantially reduce costs, energy and GHG emissions

1.5 CAUTIONS AND LIMITATIONS

The Integrated Water Management and Land Use tool provides a systematic, rational and quantitative method of evaluating the costs, benefits and effectiveness of various water conservation measures. Yet, due to gaps in data and simplifying assumptions within the tool, it is best for planning and visioning. In particular, this tool should not be used in place of a more specific hydrological analysis to calculate volumes of stormwater runoff.

The tool was primarily designed to fill a hole in the ability to analyze lot and neighborhood choices, while evaluating cumulative impacts over time. [IMAGE 1.12] Because it began with the lot and the neighborhood, the model fits these scales of analysis best. Additionally, though relying on the best available data, there are still holes in the available information. As data is increasingly available on the water impacts of these developments, it will be possible to better calibrate the models.

Finally, the tool is most reliable when comparing specific alternatives at the same site. For example, assessing changes in the water and cost metrics if a brick patio is substituted by turf grass on one lot will be reliable: costs, runoff rates and water consumption are well documented for these materials. In contrast, comparing the costs and benefits of bioswales in one neighborhood versus bioswales in another neighborhood will be less accurate. These calculations are difficult due to variations in microclimates, topography and soil types. Installation costs, maintenance and lifespan data is also less developed for relatively new LID and LEED strategies.

The accuracy of the results from the tool will vary depending on location, land covers being analyzed, the scale of analysis, and the metric under evaluation. It is up to the individual user to review the calculations and assumptions, update the tool with local data, and apply the tool with caution. [IMAGE 1.13]

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2 TOOL DEVELOPMENT

2.1 REVIEW OF EXISTING TOOLS

Prior to developing a new tool, we surveyed the existing tools that quantify various water supply benefits. Many cities and organizations are already committed to installing Low Impact Development (LID) and Green Infrastructure and have developed their own tools (including guides, reports and calculators) to guide practitioners. By reviewing the existing body of tools and literature we were able to:

1. Inventory the key factors and criteria they used to develop their tool and understand their relevance to our work;
2. Understand the context of each project and what contributed to their successes and failures;
2. Identify gaps in knowledge, and determine if we can address those gaps with our tool.

Existing water supply benefit tools are summarized in Appendix 1 with the following attributes:

ATTRIBUTE	DESCRIPTION
Toolkit Name	Toolkit name
Tool type	Calculator, guide or report. Calculators were further classified as being a web-based tool, or a downloadable Excel-based tool.
Year	Year produced or published.
Creator	Lead organization responsible for tool development.
Description	Additional relevant information about the tool, its development, or application.
Location	Region for which the tool was developed.
Inputs	If a calculator, the factors included in the calculations.
Outputs	If a calculator, the type of numbers produced (e.g., dollars, water volumes).

➤ SUMMARY OF EXISTING TOOLS

Most "Low Impact Development tools" were guides and reports. These various reports and guides listed development techniques, potential costs and benefits of LID, and often highlighted case studies of successful LID projects. The second type of tools we found were LID and stormwater calculators, which came in two formats, web-based and Excel-based. These calculators were often created by city and county governments. Most were localized to a specific city region, though one was national. A summary of the most relevant tools is provided below:

LID Calculator (Los Angeles County)

One of the few tools we were able to find within California was created by the County of Los Angeles Public Works Department. This tool, called a "LID calculator" had the goal of mimicking "the undeveloped runoff conditions of the development site with the post-development conditions" (Landscape Institute, 2012). The tool is designed to help developers comply with local regulations for managing stormwater on site. There are two tools, one for running scenarios to reduce runoff volume, and one for reducing the rate of runoff. Inputs include area, percent impervious surfaces, and soil type for calculating runoff rates; and area, percent impervious surfaces, soil type, rainfall amount, flow path (ft) and slope for calculating runoff volume. The user can use the pre-built calculator interface which does not show the calculations, but the Excel interface is still accessible to view the underlying assumptions.

As the tool was developed for regulatory compliance purposes, it is more prescriptive (calculating runoff reductions) rather than a cost-benefit analysis of green infrastructure as a whole and is not concerned with ancillary benefits of green infrastructure such as greenhouse gas reduction, or cost-savings when compared with traditional hard infrastructure solutions. In addition, it assumes that green infrastructure will be used to meet stormwater management requirements, but does not provide the background detention and retention calculations of each strategy. The calculator is useful for understanding how to properly size BMPs to meet runoff volume goals, but otherwise does not meet the needs of our tool.

BMP Sizing Calculator (San Francisco Public Utilities Commission)

The BMP Sizing Calculators developed by the San Francisco Public Utilities Commission appear to meet the same goals of the previous tool —to meet the regulatory compliance requirements for managing stormwater in San Francisco. The decision is not between green and gray infrastructure, but between the different green infrastructure strategies.

Similar to the Los Angeles tool, the BMP Sizing Calculators help developers determine the combination of green infrastructure strategies to implement to reduce runoff rates and volumes using an Excel-based platform. The calculator asks the user to classify the project area as impervious or pervious and allows the user to select from surface types with different runoff coefficients. Unlike the Los Angeles tool, the BMP Sizing Calculators take into consideration the specific detention and retention characteristics of a suite of green infrastructure strategies including the following:

- Detention pond
- Wet pond
- Infiltration Basin
- Infiltraiton trench
- Vegetated swale
- Constructed wetland
- Rainwater harvesting
- Vegetated roof
- Permeable pavement

The tool does not allow, however, for cost comparisons between traditional and green infrastructure, and does not include ancillary benefits of green infrastructure. Additionally, with very detailed inputs and outputs, the interface can be challenging for non-technical users who lack previous training in hydrology.

National Storm Water Management Calculator

One of the most comprehensive and intuitive calculators we found was the National Storm Water Management Calculator created by the Center for Neighborhood Technology. The National Green Values™ Calculator (GVC) is a web based calculator designed to quickly compare the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), to conventional stormwater management practices.

According to the GVC User Manual, the GVC attempts to do a holistic cost-benefit analysis for the full life cycle of the site including the first-time construction costs for the developer, as well as the life cycle operation and maintenance costs and benefits to the public and to the private property owner. Included in the benefits analysis are the dollar values for the carbon sequestration capacity and groundwater recharge, as well as an estimate of the increased property value from enhanced tree cover.

The GVC is centered on runoff volume reduction. It is designed to take the user step-by-step through the process from determining the average precipitation at a site, to choosing a stormwater runoff volume reduction goal. From there, it guides the user to characterize the impervious areas of your site under a conventional development scheme, and then choosing from a range of Green Infrastructure Best Management Practices (BMPs) to find the combination that meets the necessary runoff volume reduction goal in a cost-effective way.

As previously stated, the GVC is focused on runoff volume reduction (infiltration, evapotranspiration and reuse) and does not examine impacts on peak flows. The tool does not include detention in ponds or vaults as options for runoff volume reduction, and all runoff volume captured in BMPs is assumed to be kept on site. The tool does include a wide portfolio of green infrastructure strategies in its cost calculation, as well as a number of quantified benefits of green infrastructure such as:

- Reduced air pollutants,
- Carbon dioxide sequestration,
- Compensatory value of trees,
- Groundwater replenishment,
- Reduced energy use, and
- Reduced treatment benefits.

One limitation of this interface is that it is difficult to save calculations and adjust scenarios. The numbers and formulas are 1) hardcoded, and 2) hidden behind the user interface. As such, we cannot learn about how their tool was developed, or what their assumptions are, and we cannot customize the tool for local conditions. Secondly the tool uses a vast array of data from all over the nation for its calculations, which creates a limits the accuracy in its monetary output. Lastly, the GVC was designed to be applied to a single site or a campus of buildings contained on a single site and cannot be scaled to the neighborhood or beyond.

Green Infrastructure Valuation Toolkit

The tool we found which aligned the most with our objectives is from England. Called the Green Infrastructure Valuation Toolkit, it is an excel-based calculator which consists of a "set of individual spreadsheet-based tools to assess the value of green assets or projects across a wide range of potential areas of benefit - such as climate change, health, or property values" (Building Natural Value for Sustainable Economic Development, 2012).

According to the Toolkit User Guide, it looks at how the range of green infrastructure benefits deriving from an asset or investment can be valued:

- in monetary terms—applying economic valuation techniques where possible
- quantitatively—for example with reference to jobs, hectares of land, visitors
- qualitatively—referencing case studies or important research where there appears to be a link between green infrastructure and economic, societal or environmental benefit, but where the scientific basis for quantification and/or monetization is not yet sufficiently robust.

The User Guide acknowledges the limitations of the tool as well. The tool is based on 11 groups of green infrastructure benefits; however, overlap exists between some groups and it is possible for benefits to be double-counted. In addition, as is the case with many tools, the Toolkit uses assumption-based factors based on a limited body of evidence. While developers built in the option to tailor the toolkit to local conditions when good local data is available, they feel that it would lack sufficient rigor to permit anything more than indicative valuation results. Therefore, the developers themselves feel that the toolkit outputs will remain broad scale and contextual.

This tool offers many of the qualities we are aiming for in the creation of our tool including being in an Excel-based format and all-encompassing of the costs and benefits but it was developed for a UK economy and environment, and not have the detail we want in terms of the land cover options and the suite of green infrastructure to evaluate.

Urban Footprint

One of the most recent tools developed for assessing development impacts in California is Urban Footprint, created by Calthorpe and funded by the California High Speed Rail Authority and the California Strategic Growth Council. Urban Footprint assesses a variety of urban development impacts, not just water-related metrics.

Unlike the other tools we reviewed, we were not able to directly interact with Urban Footprint. The model is not yet available to the public. When it is released, it will initially be distributed as a series of python scripts with a base dataset (Mike McCoy, pers. comm.). Urban Footprints technical summary notes that the model is raster-based with 250ft grid cells (CITE), which is efficient for a large area, but coarse for lot or neighborhood analyses.

Urban Footprint is best suited for expert users comparing impacts of city, county, regional and state growth decisions.

➤ GAP ANALYSIS

Based on our preliminary assessment of existing tools, many of the calculations we would like for our tool have been research and developed, and are available in many separate tools. There is no single tool, however, which incorporates all the calculations we would like to include at:

MAIN TAKE-AWAY POINTS
1. Web-based tools are hard coded.
2. Excel-based tools offer more flexibility.
3. No locally calibrated models.
4. Lot and neighborhood scale is rare.

Web-based tools were much more visually appealing and easy to use. These tools were useful for understanding the inputs and outputs often considered in tool development, and the importance of creating a user-friendly interface. However, the source information was often hidden so that we could not 1) see the numbers or formulae they used for their calculation methods, and 2) change the variables if we wanted to customize the calculations using locally derived data from our area.

There is currently a lack of tools that are locally modifiable, to reflect community-specific costs and benefits. Existing tools were often locked or hard-coded, and prohibited adjustment of background numbers in order to calibrate the tool to local information or conditions, refine background numbers based on new research, or add new technologies as they become available. An unlocked excel-based tool would provide the desired flexibility. Excel is widely-available and accepted software, making the customization process easier.

The last void we found in our search of existing tools is spatial scalability. Currently no tool exists that allows the user to scale a project up from the parcel, to the block or neighborhood, and on to larger spatial regions. This makes it difficult to assess cumulative impacts of local actions.

2.2 TOOL OVERVIEW

After reviewing existing tools, it became clear that it is difficult to customize, save, scale, and test scenarios with existing tools. Many tools had challenging user interfaces, and in some cases required considerable background knowledge. Few tools brought together a suite of integrated water management metrics. In response, we sought to create a tool which is accessible, modifiable, scalable, and comprehensive.

➤ ACCESSIBLE

One of the primary objectives of the tool was to create an interface that is accessible to non-technical users who may have less experience in hydrology or water resource management. We want home owners, developers and planners to feel comfortable with the tool interface, the data inputs, and the data outputs. These values are reflected in the tool through the following choices:

- **Excel-based**. Microsoft Excel is commonly available and widely familiar.
- **Simple inputs**. We sought to identify the smallest number of data inputs that could be easily measured and reasonably address our multiple water metrics. This was an iterative process, refined by discussions with landscape architecture and hydrology professionals, by lessons learned when applying the tool to the case study sites, and from constraints of the Excel interface. After several rounds of testing, we identified a streamlined set of inputs.
- **Clear outputs**. Beyond being comprehensive, the metrics used in this analysis were selected for their clarity. Outputs can be visualized and compared relative to one another. People without backgrounds in hydrology can assess and understand the relative impacts of different development choices.

➤ MODIFIABLE

This tool is open and transparent. Any user may alter the tool as they see fit.

- **Update with local data**. Given the varying environmental conditions and construction costs through California, locally-specific data is essential to reliable calculations. The tool we developed is calibrated to Sonoma County, the site of our test studies. Cost information and weather data are focused on Sonoma County. Some of the data from Sonoma County will hold true elsewhere, while other information may not. Users with knowledge of their local environment and construction costs may easily update the too—just click on the Data tabs and change the background information.
- **Alter calculations**. Similarly, if a user is interested in a calculation, all cells are unlocked and modifiable. Any calculation can be updated to better reflect new policies, emerging knowledge, or locally specific needs.
- **Build your own scenarios**. Water smart development is not all or nothing. There are a range of solutions which are appropriate in different locations and meet different project goals. As a result, we created the tool to act like a menu. Choose the features that are best for your site. Add new data inputs to the tool as you like. Everything can be customized.

➤ SCALABLE

The tool allows the user to examine water supply benefits at many spatial scales. The most accurate results come from the lot and neighborhood level, where users can fine tune land areas, water consumption and the cost of components to compare different development scenarios. The user can also save custom neighborhood profiles.

Beyond the neighborhood, the tool accepts inputs of acreage for pre-defined neighborhood types (including any custom neighborhoods). The tool scales output values by neighborhood area. For example, a user may decide that a town is comprised of 70 acres of Traditional development and 30 acres of SUSMP development.

Extrapolating from the neighborhood, as is done within the tool, is subject to many inaccuracies. One challenge is that it is necessary for the user to categorize the whole area into a smaller subset of neighborhood types. This may prove to be difficult, particularly in areas that have been slowly developing over a long period of time since development styles change incrementally. An additional challenge is that the tool assumes that all the areas within a neighborhood category will have the same outputs. In actuality, differences in behavior and microclimates may cause two areas that are similarly developed to exhibit different resource use.

All inaccuracies in the neighborhood specifications will compound when scaled over larger areas (e.g., watersheds). Yet, despite the limitations of bottom-up projections—as is done within this tool—extrapolating regions from neighborhoods is a valuable method for envisioning the cumulative impacts of small choices.

Because of the difficulties of extrapolation, any applications of tool beyond the neighborhood should be approached with caution and a critical eye. For a more accurate analysis of broader spatial scales, it may be best to implement Urban Footprint.

➤ COMPREHENSIVE

Because the objective of this tool was to broadly consider costs and benefits of land use planning for integrated water management, we sought a comprehensive set of metrics which addressed water quantity, water quality, flood risk, habitat, and climate change adaptation and mitigation.

Refined over multiple iterations, we ultimately chose to focus on impervious surfaces, storm water runoff, outdoor irrigation requirements, greenhouse gas emissions associated with outdoor water use, and the monetary costs of implementing a land use/land cover plan. These metrics were selected because they were useful, sensitive indicators of water supply benefits, while also possible to derive from streamlined inputs and transparent calculations.

2.3 TOOL METRICS AND DATA

Following is a discussion of the data and assumptions made while creating the Integrated Water Resource and Land Use Planning tool. For detail on the calculations used within the tool, see Appendix 4.

➤ WATER RUNOFF

Overview

Water runoff is a critical target of water-smart development, but is also difficult to quantify with simple inputs. There are several tools available which support comprehensive stormwater analyses. In Northern California, San Francisco Public Utilities Commission's Stormwater Calculator and the Bay Area Hydrological Model (BAHM) are excellent examples (CITE). Both of these tools, however, require detailed inputs and are give outputs which are most suited toward users who are familiar with hydrology.

In contrast to the detail in the existing tools, we chose to focus on the following planning-scale metrics:

Percent impervious surfaces
Although a simple metric, percent imperviousness is useful indicator of overall watershed health (CITE). In addition, many LID designs target reducing impervious surfaces with interventions such as limited road widths, smaller driveway footprints, and substituting out impervious materials.

Peak runoff from impervious surfaces
The maximum runoff helps approximate the necessary amount of water infrastructure, whether for on-site retention or traditional stormwater conveyance. While precise volumes must be calculated with calibrated hydrological tools, this figure aids in comparing scenarios.

Figures and sources

Impervious surfaces

To calculate percent impervious surfaces, all fully impervious surfaces are summed for the study area and divided by the total study area. Fully impervious surfaces include:

- Asphalt
- Concrete
- Pavers, brink or natural stone with concrete joints
- Traditional (non-green) roofs

The area of each surface is from user-contributed data on land cover.

Rainfall

The tool calculates peak monthly runoff from fully impervious surfaces. Users may modify the tool to calculate runoff over different periods. For example, it is be possible to derive runoff for a typical LID design storm (24 hour storm), a typical pipe infrastructure design storm (100 year) (Storm Water BMP, 2005). We focused on monthly data because this was a time frame that worked well across all of the metrics. Monthly rainfall data is available from the California Irrigation Management Information System (CIMIS). We relied on a 10 year averages from the Santa Rosa CIMIS station (Santa Rosa Area Reference, 2012).

Data limitations

Calculating runoff

One of the significant limitations of our method is that we are only evaluating runoff from fully impervious surfaces. We do not evaluate runoff from land covers that have some degree of permeability. For example, we do not assess the runoff contribution from turf grass which, depending on soil type, compaction, and slope, can be significant. Yet, calculating runoff from semi-permeable surface would require several different additional inputs: soil, surface conditions/roughness, and slope. Requiring such inputs would dramatically increase the complexity of the necessary input data. This major simplifying assumption was necessary in order to maintain streamlined, accessible user inputs.

Mitigating runoff

In this model, we assume that there are four factors which mitigate runoff: rain barrels, rain gardens, bioswales, and ponds. We do not assess pools, which may have some retention effects, due to large variability in retention value.

> **Rain barrels**. We assume that rain barrels can store their full volume of water in a month. In reality, there may be multiple months that a rain barrel is never emptied (and, thus, not refilled), or there may be a month where the rain barrel is emptied and refilled multiple times.
>
> **Rain gardens, bioswales, and ponds.** All rain gardens, bioswales and ponds are assumed to retain and infiltrate one foot of water on a monthly time frame. In other words, each infiltrates a volume equal to the area of the rain garden/bioswale/pond. This is a coarse assumption. In actuality, rain gardens, bioswales and ponds may be able to retain more or less water. Also, in periods where there are smaller, regular storms or in sandy soils, it may be possible to infiltrate a greater amount of water. At times when there are heavy storms, or in areas where there are clay soils, there may be less infiltration.

Add photo or graphics

Qualitative considerations

Runoff velocity

One of the objectives of stormwater runoff management is to ensure that an area retains its pre-development hydrology, both in the quantity of runoff and the rate at which the runoff flows. An increase in impervious surfaces reduces the surface area where water can infiltrate, while increasing the speed at which it flows. This combination can have serious impacts downstream, including erosion of the waterway, habitat loss, and increased risk of flooding (CITE).

The speed of water runoff, also known as Time of Concentration, is an important factor that is not considered in this model. To calculate Time of Concentration number it is necessary to identify slopes, soil conditions, and surface roughness, which are overly complex for this tool. In general, the percent increase in impervious surfaces is a good proxy for evaluating impacts of runoff velocity.

Capturing rainwater

Because rain gardens and bioswales reduce the volume and speed of water runoff, it may seem as though this tool promotes rain gardens. It is worth noting, however, that experts do not agree on the efficacy of large stormwater detention basins (CITE). Critics claim that important sediments are trapped in detention basins, which contributes to downstream erosion.

Rain barrels can also be controversial. While popular, local water storage is often critiqued in California's monsoon climate. With heavy winter rains, it is often difficult to capture enough water on site to significantly impact water runoff. With long, dry summers, it is also difficult to capture enough water to significantly decrease supplemental irrigation requirements. Rain barrels may be more effective in climates which receive rain throughout the year.

The complications of capturing rainwater are arguments for focusing on reducing impervious surfaces. Maintaining pre-development hydrology is best accomplished by limiting the amount of new, impervious surfaces that introduced to the watershed. Mitigating is not as effective as avoiding new impervious surfaces.

➤ APPLIED OUTDOOR WATER

Overview

There are several steps to calculating outdoor water requirements. In this tool, first we calculate the overall theoretical irrigation requirements based on vegetation categories. This is also known as the crop coefficient method. It requires the following data inputs:

- Evapotranspiration zone (ET)
- Species-specific plant water use coefficient
- Planting density
- Environmental exposure
- Irrigation efficiency

After identifying the overall theoretical irrigation requirement (in gallons of water), for households with weather-based irrigation controllers we assume that there is an irrigation efficiency gain that reduces total outdoor water requirements by an overall percentage. The theoretical irrigation requirement is reduced by this percentage. Next, we subtract from the required volume of water all available sources of non-potable water, such as rainwater storage. We assume that all remaining water needs are met by applying standard potable, municipal water.

Figures and sources

Evapotranspiration zone

Information on the inches of water evapotranspired per month from a reference surface (e.g., grass) is available from the California Irrigation Management Information System (CIMIS). We relied on average reference evapotranspiration (ET) by zone, as published by CIMIS and reproduced within the tool (ETO Zones Map, 1999). We focused on peak monthly reference ET. In Zone 5, where Santa Rosa is located, this is 6.51 inches of water. In contrast, there is an average monthly reference ET of 0.93 inches in December and January. The user may select any month with calculating outdoor water requirements.

Species-specific plant water use coefficient

In California, species-specific plant water use coefficients are available from the Water Use Classification of Landscape Species (WUCOLS) study, developed by the University of California Cooperative Extension (Water Use Classification of Landscape Species, 2012). For the purposes of this tool, however, species-specific calculations were overly detailed. Instead we chose to follow coarser categories of water use coefficients offered by Sonoma Master Gardner, also available through the UC Cooperative Extension (Master Gardener, 2012).

Irrigation efficiency

The percentage of water that is successfully applied to the roots of a plant varies by irrigation method. Drip irrigation methods are found to be up to 90% efficient, while surface sprinklers are approximately 60% efficient. CITE In a DWR water budget calculator made available through the Model Landscape Ordinance, default irrigation efficiency is given to be 71% (Model Landscape Ordinance, 2011). We chose to remain consistent with this value.

Irrigation controllers

There are two forms of irrigation controller, the automatic clock driven irrigation systems and the smart or weather-based controller. Automatic controllers may provide inefficient and excessive water delivery when they are not synchronized with soil moisture. Weather-based controllers, the new generation of irrigation controller, adapt watering volumes and schedules to best reflect with actual water needs. The 2009 "Evaluation of California Weather-Based 'Smart' Irrigation Controller Programs" concluded overall outdoor water use was reduced by an average of 6.1% when using a weather-based irrigation controller (CITE).

Data limitations

While WUCOLS provides useful guidelines on water use, actual use may be higher or lower, depending on topography, solar exposure, wind exposure, soil types, mulching practices and irrigation efficiency. It is likely possible to improve the accuracy of these calculations with more localized data.

Planting density

Areas that have a high density of plants tend to consume more water. As a result, the crop coefficient method typically includes a variable for planting density. In aerial imagery examined for the case studies, we found that separating areas into sparsely an densely planted vegetation was straightforward and useful. Nonetheless, guidelines on water consumption of sparse versus dense vegetation are somewhat difficult to match with real world conditions.

Environmental exposure

Within theoretical irrigation requirement calculations, some of the impact of microclimates on water use is accounted for by an exposure multiplier. To maintain simplicity in this tool, we chose to assume a constant exposure. This assumption should be reasonable over larger areas and comparing scenarios at the same site. This assumption would be problematic, however, if comparing a sheltered, north-facing site to a windy, south-facing site.

Qualitative considerations

Using non-potable sources of water to meet irrigation demands is increasingly common. Two sources of non-potable water which are gaining popularity are:

Municipal recycled ("purple pipe") water is now available in many places in California. Because recycled water is often not treated to the same degree as potable water, in some regions this may be a less energy intensive method of meeting irrigation requirements (CITE). At present, recycled water is not built into the tool, but it would be a relatively straight forward addition.

Home greywater systems can be an inexpensive method to supplement irrigation of outdoor landscaping, particularly if the system is from a single fixture and qualifies for an exemption from local permit requirements. More complex gray water systems, also restricted to non-potable uses such as outdoor landscape irrigation or indoor toilet flushing, may also be pursued. Because of California's seasonal rainfall, water storage needs and costs are an important consideration, and on-water sources, if available, may be more cost-effective for outdoor irrigation. Water volumes contributed by gray water systems may be entered into the tool. (CITE)

➤ GREENHOUSE GASSES FROM OUTDOOR WATER

Overview

Water related energy use accounts for 19 percent of California's total electricity use and almost 30 percent of natural gas use (Integrated Energy Policy Report, 2005). Both the California Energy Commission and the California Public Utilities Commission concluded that the energy embedded in water presents an opportunity for cost effectively reducing greenhouse gas (GHG) emissions.

The energy embodied in a unit of water varies with location and source. Moving large quantities of water long distances, distributing it within communities, and treating the resulting wastewater are all energy-intensive processes. For many communities, including Sonoma County, the energy required for supplying and treating water and wastewater represents the largest municipal energy cost.

The data within the tool is focused on the GHG emissions embedded in municipal water within Sonoma County. Compared to many other regions, there is little energy consumed by water provision in Sonoma County. This is because the county collects ground water which is naturally filtered through the gravels of the Russian River. The water requires no additional treatment prior to household consumption. In other area in California there may be large energy expenditures associated with water treatment.

Instead, energy is primarily embedded in Sonoma County through water pumping. Groundwater is pumped from approximately 60 feet below ground and then lifted, via booster pump stations to storage tanks which are located at a higher elevation than the water customers. Once the water is in the storage tanks, it is delivered to customers by gravity (SCWA Water Supply and Transmission, 2013).

Additional energy is used in wastewater treatment. This energy expenditure is not applicable to this tool, however, because of the tool's focus on outdoor water use. Unlike household water, outdoor water runoff enters storm drains which empty into nearby creeks and streams. Outdoor water runoff is not treated (Storm Drain Systems vs. Sanitary Sewer Systems, 2011).

Figures and sources

Using observed energy intensity ratios from the Sonoma County Water Agency for the groundwater pumps and booster pumps, we are able to assess the total energy intensity in kilowatt-hours per every million gallons of water used in the Agency's territory (Embedded Energy In Water Studies, 2010). Then using PG&E's GHG emissions factor (specific to Sonoma County electricity sources) we are able to find the total GHGs emitted per unit of water consumed.

After calculations, we concluded that Sonoma County water contains approximately 160 pounds of carbon dioxide in every million gallons of water delivered. This is approximately the equivalent of combusting 8 gallons of gasoline (U.S. Energy Information Administration, 2012).

Data limitations

GHG estimates are based on records of energy-use and the electricity provider's GHG emissions coefficient. In Sonoma County, this means kilowatt-hours used for pumping groundwater as reported by the jurisdiction and the Pacific Gas & Electric carbon dioxide coefficient as reported to the California Public Utilities Commission and Climate Registry. Any inaccuracies in energy or emissions data will be reflected in GHG calculations.

Other jurisdictions in California (where ground water is not the source) may have to consult the CPUS's "Embedded Energy in Water Studies 1,2, and 3" (CP, 2012) to determine the amount of energy used to pump water from sources outside the jurisdiction. If the jurisdiction has a combined sewer system that also collects water in storm sewers for treatment along with wastewater from households, energy for sewer pumping and wastewater treatment will also need to be included.

The Climate Registry and California Air Resources Board publish carbon dioxide coefficients for most California utilities. The amount of carbon dioxide will depend on the power supply portfolio for each utility. These coefficients are not third-party verified, but are refined periodically. Generally, GHG emissions calculations are estimates as not all levels of lifecycle analysis can be included, but they are useful for prioritization and comparison.

Qualitative considerations

In jurisdictions like Sonoma, using recycled water may not have significant benefits with respect to carbon dioxide emissions. Water providers importing water from distant sources or utilities that treat stormwater and runoff in a combined sewer system may see more significant energy savings by using recycled water. A simple rule is that the closer to the site the water source is and the less wastewater that has to be moved and treated, the less energy used and the fewer GHGs are emitted.

Yet, the benefit of recycled water is not exclusively tied to energy efficiency. In general, using recycled water can lessen a region's dependence on important water supplies. In the case of Sonoma County, recycled water may help conserve groundwater reserves and reduce the risk of depleting the aquifer.

➤ PROGRAM COSTS

Overview

The cost metrics assess the monetary costs of a land use/land cover and water infrastructure plan. The tool considers upfront costs of installation (materials + labor), the cost over 50 years, and the cost over 100 years. We selected these time frames to correspond with standard infrastructure lifecycle calculations performed by the state and the federal governments, respectively. In order to calculate costs, it was necessary to find prices for many different land covers (see Appendix 2). These costs were localized to Sonoma County.

Figures and sources

Cost estimates were collected in Sonoma County from June through November 2012.

Recognizing that prices can vary depending on location, time of quote, and scope of the project, we sought multiple sources for each specification. Sources include private contractors, commercial contractors, landscape developers, plant nurseries, public agencies, building supply stores and online materials reference guides.

There was often a wide range in prices. Different construction companies and suppliers charge different prices for labor and materials. In the tool, we relied on the average value from multiple quotes.

When a cost was not available from a Sonoma County source, we sought the most localized available information. For example, stormwater pipe cost information was sourced from RS Means, which provides generalized data for all of California.

Data Limitations

Data Availability
Some of the challenges we faced in gathering price data included reluctance from sources to give prices for data purposes, construction companies were often too busy at the time to provide price estimates, and hesitant in having their estimates be used in a published report.

Lack of data was particularly problematic for green infrastructure. There are few companies who install LID components and the field has a shorter history, so price quotes are not as well developed. In these cases, the single quote often became the working price within the tool.

Price Variations and Reliability
Using single quotes, or even average quotes, simplifies the variability in quality of materials and construction. The tool data will best reflect median construction practices.

Project Scale. There are typically large economies of scale in construction. For example, when pricing out rainwater harvesting tanks, the price per gallon decreases as the tank size increases.

To be implemented in the tool, however, it was necessary to break down estimates into units such as price per square foot, per linear foot, per count, or per gallon. This allows the user to input an area, size, or quantity and calculate the corresponding cost. For example, if concrete is $1.00 per square foot and a user inputs 4 square feet, the result will be $4.00.

Future iterations of the tool may consider creating steps of price data dependent on the quantity of product.

Lifecycle Costs. Calculating long term costs is challenging. There is a wide degree of variation in both component lifespan and ongoing maintenance costs. Materials, construction methods, environmental conditions and owner behavior will all influence the lifespan and maintenance costs of a particular component.

In general, product lifespan data is available, even though it is uncertain. The lifespans recorded in the tool were from reliable sources with significant experience in the Sonoma County area.

Maintenance data is less available than lifespan data. While there is more information on maintenance for traditional, grey infrastructure than green infrastructure, it is still difficult to come by. Due to the sparse and asymmetric information, in this version of the tool we chose to not include ongoing maintenance in cost calculations. As more data becomes available, this will be an easy and valuable addition.

Qualitative Considerations

Calculating costs poses many different questions of externalities, both positive and negative. At present, we are not able to feed the impact of externalities into cost calculations; the full web of cost connections is complex, not well understood, and poorly documented. Instead, we consider the straight costs of products and labor. There are several places where issues of externalities are clear, however. Following are three examples.

Maintenance Costs
One reason maintenance costs may not be well document is because the person who purchases the product up front is often not responsible for long term care. For example, while a road might be installed by a local developer, the city may take over maintenance after some period of time. Similarly, if a roadside bioswale is installed by a local developer, the city may become responsible for landscape maintenance.

In general, the more infrastructure that is installed across the city, the more maintenance costs are created. Yet, within infrastructure, some choices require less expensive maintenance than others. Wise planning will help minimize long term costs.

Home Values
Many studies indicate that increased vegetation and community open space have positive impacts on home values CITE. As a result, when developing, it is likely possible to recuperate more of the costs of green infrastructure than grey infrastructure. If it were possible to input cost recovery, it is likely the tool would reveal a stronger case for green infrastructure.

Greenhouse Gasses (GHGs)
As present, the GHG metric from the tool strictly calculates the amount of GHGs generated by applying outdoor water. This grossly underestimates the GHG contribution of one land plan versus another, since GHGs are embedded in all of the components of creating and maintaining a land plan, not just applied outdoor water. While it is difficult to assess the GHGs embedded in each individual component within the tool, future development may include some coarse metrics. In general, any substitutions of green infrastructure for grey infrastructure should diminish GHG contributions.

K-1

Add photo or graphic

3 CASE STUDIES

3.1 OVERVIEW

➤ SELECTING CASE STUDIES

The objective of applying the tool to case studies was to test the and develop the tool in the context of real-world examples and then to analyze the differences of real land use alternatives in Sonoma County with metrics from the tool.

After speaking with local planners and water experts, we selected four case study sites which were representative of a cross-section of water infrastructure possibilities. In this report, each case study is named after its stormwater policies or practices: Traditional (pre-regulation), SUSMP, GreenPoint, and One Planet.

Stormwater Policies and Practice

The case study sites were selected to highlight evolving stormwater management techniques. Each case study adheres to different stormwater policies and practices, guided by federal, state and local storm water regulations active during project approval (*for detailed requirements, see Appendix 3*).

The first case study, Traditional, was constructed prior to stormwater regulations. Stormwater runoff regulations were first enacted in California in 1987, when the Federal Water Pollution Control Act (Clean Water Act) was amended (Storm Water Permit, 2012).

The second case study, SUSMP, was built in 2005 after stormwater regulations were updated with the more restrictive Standard Urban Stormwater Management Plan (Guidelines for the Standard Urban Storm Water Mitigation Plan, 2005).

The GreenPoint and OneWorld developments voluntarily chose to exceed the standards put forward in regulations which were in place during project approvals. The GreenPoint case study incorporates storm water measures from CALGreen. The One Planet case study implements both LEED and One Planet Community standards.

An additional regulation, the Water Efficient Landscape Policy (WELP), was enacted in 1993 the City of Santa Rosa. WELP included regulations on irrigation equipment, landscaping on steep slopes, rain sensors, auto shutoff, and hydrozoning techniques (Water Efficiet Landscape Policy, 1993). WELP was superseded by SUSMP. None of the case studies were built to WELP standards, and thus WELP is not addressed further.

Challenge

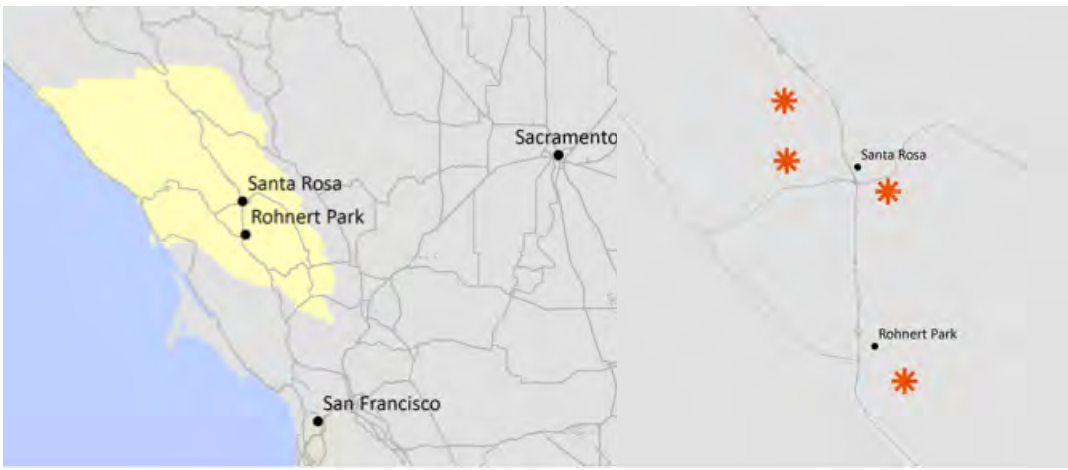
The existing, statewide stormwater policy is CALGreen, implemented in 2011. Since CALGreen was approved, there have been no new developments built in Sonoma County. As a result, it was not possible to include a case study approved under CALGreen in our analysis.

In general, there has been minimal building activity in Sonoma County following the onset of the 2007 recession. The GreenPoint development is only partially built with 12 completed lots. The One Planet development is not built and can only be evaluated through design documents and Environmental Impact Reports.

Nonetheless, even with limited data on new developments, it is possible to perform some initial studies. Further vetting against built land covers and recorded water data will soon become possible.

➤ REGIONAL CHARACTERISTICS

Location



The case study sites are located in central Sonoma County, in the cities of Santa Rosa and Rohnert Park. Rohnert Park is home to 43,062. The median household income in 2000 was $51,942, and rose to $67,097 in 2007 (Demographic Profile, 2010). Santa Rosa has a population of 169,292 as of 2011 (Santa Rosa, Ca Quick Facts, 2013). The median household income is $59,838 in 2009 (City Profile, 2010).

Climate

Santa Rosa's climate is moderate temperature and precipitation. Most of the annual precipitation is concentrated in six months of the winter season. Typically Santa Rosa will experience approximately 32 inches of rain per annum (Now Data, 2012). Rain intensity can be as high as .5 inches to .8 inches an hour once every two years reaching higher levels of 1.1 inches to 2.0 inches an hour once every 100 years. Six hour rain intensity for every two years ranges from 2-3 inches with a 100 year intensity of 3.8 to 6.3 inches in a six hour period (Climate of Sonoma County, 1964).

➤ TRANSLATING FROM SITE TO TOOL

In order to analyze our case study sites with the tool it was necessary to identify unique land cover types, quantify the area of each land cover, and identify water infrastructure. For the built developments (Tradition, SUSMP and GreenPoint), we used high resolution aerial imagery in a Geographic Information System (GIS) to identify and measure land cover. We confirmed GIS findings with site visits.

Interpreting land cover with GIS

Aerial interpretation was done with images acquired from the City of Santa Rosa. We used the Northwest and Southwest quadrants, flown in 2009. While more recent aerials are available from other sources, the 2009 imagery was the only with sub-meter resolution. High granularity was essential in order to digitize different land covers as accurately as possible.

Even so, it was often challenging to tease apart different land cover types. Defining land cover categories became an iterative process, balancing the inputs necessary to quantify unique water consumption, runoff and program costs, while maintaining a set of variables which could be interpreted in the GIS.

Following are the final set of land covers identified within the case studies:

Impervious surfaces	Vegetation	Public space
Asphalt	Turf grass	Maintained (e.g., lawn)
Concrete	Dense vegetation	Natural/naturalized
Pavers and Brick	Sparse vegetation	
Composite roof	Natural/naturalized vegetation	

Using aerial photos presents several challenges that can impact the accuracy of land use categorization and defining boundaries. Some challenges were:

Skewed aerial photos. The aerials are taken at an angle, not directly overhead, which caused fences and walls to be visible. Walls were counted as roof lines as they would be covered by the roof if the view was from straight above each lot. Fences were cut in half and incorporated into the land use section that was closest to the fence.

Shadows. When shadows were present, the team looked to similar lots to see what was most likely in the shadowed areas.

Temporary land cover. When trash cans or other unidentifiable objects seemed to be in place temporarily, the land use was categorized as what was underneath it by using the surrounding area land uses as our best estimate. Trees with no leaves were given a conservative estimated tree canopy cover that would be present throughout most of the year.

Field verification of GIS analysis

We visited each case study site in Fall 2012. Visits to each case study site were limited to front yards and non-fenced areas. During the site visits, we confirmed GIS interpretation and assessed water infrastructure (e.g., disconnected downspouts), which was difficult to observe in aerial images.

3.2 TRADITIONAL DEVELOPMENT

➤ SITE DESCRIPTION

Residential Units: 224

Size of Development: 70 acres

Density: 4 units/acre

Initial Year of Development 1976

Storm water Codes: n/a

History

There are 224 homes within the Traditional community. The development was approved in 1974 (Policy Statement, 1974) and homes were built in three phases from 1976 to 1986.

Design

This traditional development exemplifies post WWII suburban communities. All the homes in this community are single family detached homes with one floor and attached garages. There are three type of home designs; quadraplot homes, semi-detached townhouses, and zero side yard houses. The typical home within this community is a three bedroom, two bathroom house ranging from 1,100 square feet to 2,300 square feet with the median house being 1,400 square feet. The homes sit on lots ranging from 4,000 square feet to 7,000 square feet. The median lot being around 5,600 square feet. The average density of this community is approximately 6 units per acre. A typical home in this community costs $260,000, with home values ranging from $204,000-$308,000. In the north central portion of the development there are 56 homes that differ from the normal building type in the community. These homes are smaller, are generally two bedroom, two bathroom and are approximately 1,096 square feet on a 3,400 square foot lot. In the center of this development is a community park with a basketball court and a community pool (Zillow, 2012).

(Insert Image G-1)

Demographics

Traditional Homes is located within the City of Santa Rosa. Its block group has a population of 1,637. The average household size is 3.03 persons per occupied unit; owner occupied units have a lower average of 2.89, and renter occupied units have a higher average of 3.35. The median household income of the block group ranges between $57,005 and $62,516

(American Community Survey, 2012).

(Insert Demo Pie chart)

Stormwater Management

Although storm water runoff regulations were not enacted until 1987, when the Federal Water Pollution Control Act (Clean Water Act) was amended (Storm Water permit, 2012), several measures were observed within this subdivision. For example, the vast areas of green space, particularly in the center, act as bioretention areas that allow storm water runoff to flow through vegetated areas, reducing the water's velocity and increasing infiltration.

➤ TRANSLATING FROM SITE TO TOOL

The primary challenge when digitizing the Traditional subdivision is that the trees are mature and have with large canopies which grow together. The site visit allowed us to observe the trees and adjust the tree count as necessary. Additionally, the site visit helped us identify water infrastructure which was not evident from the aerial photos. We noted downspout disconnections, but no other consistent neighborhood green infrastructure techniques.

Lot

Neighborhood

3.3 SUSMP DEVELOPMENT

➤ SITE DESCRIPTION

Residential Units: 150

Size of Development: 18 acres

Density: 9 units/acre

Initial Year of Development: 2005

Storm Water Codes: Standard Urban Storm Water Management Plan

History

The subdivision consists of 88 single family homes and 31 duplexes on 29.4 acres of land; 13 acres are set aside as preserve. The project was approved in 2005 and built shortly thereafter.

When the project was approved, the City of Santa Rosa conditioned the project so that all the additional runoff from this finished site would not exceed the pre-development flows.

Design

There are six different models of homes, ranging from 1,680 square feet to 1,716 square feet. The lot sizes and yard space vary with each models ranging from lots of 2,657 to 4,936. Development density is roughly 9 units per acre. Recently sold units ranged from low $200,000s to low $400,000s (Zillow, 2012).

Demographics

The SUSMP subdivision is located on the western outskirts of the urban center of Santa Rosa. Its block group has a population of 2,307. The average household size is 2.87 persons per occupied unit. In addition, this census tract has a median household income ranging between $58,952 and $74,443. (U.S. Census, 2010)

(demo pie chart)

Stormwater Management

Storm water runoff regulations within this subdivision are based upon SUSMP regulations. Duplexes surround the perimeter of the entire development, all of which have Hollywood driveways, characterized by two strips of turf or gravel. Such strips allow pollutants released from parked vehicles to sequester rather than be rinsed into storm drains when it rains. The remaining residences are single family homes laid out in a cluster development pattern, sharing a common driveway between four residences. This effectively contributes to a reduction of impervious surfaces and allows for greater ground water recharge. Curb cuts allow run off to flow from the street into vegetated strips, decreasing its speed and providing for a greater opportunity to infiltrate; excess water then flows through a series of medium sized stones that act as a buffer surrounding the storm drain, potentially preventing large pieces of trash from entering. The subdivision includes a detention pond and street-side bioswales.

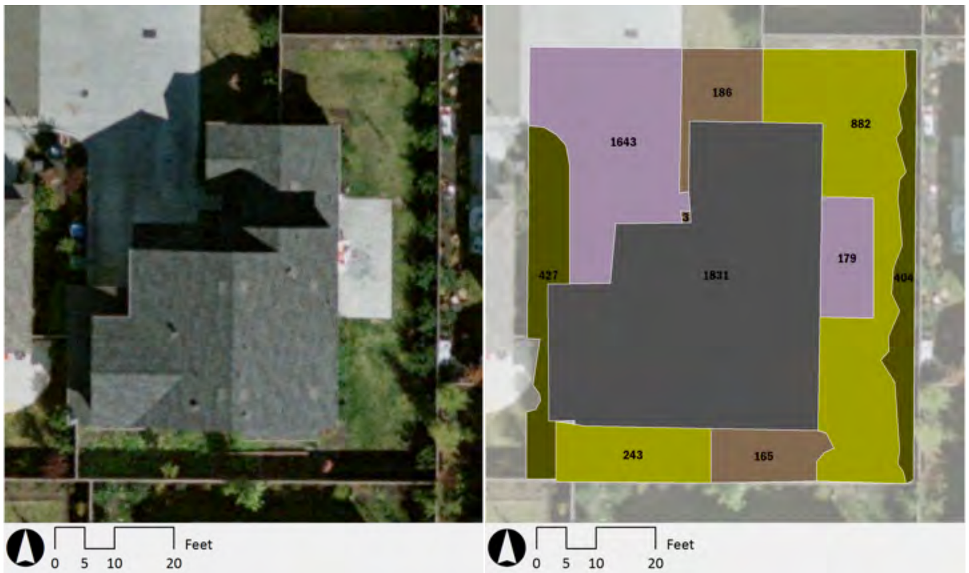
➤ TRANSLATING FROM SITE TO TOOL

The SUSMP development was easier to digitize than the Traditional development. This subdivision is newer and trees are not yet mature; subsequently, the lack of shadows and tree canopies made land covers more distinguishable. Also, as it is a newer development, the land covers are more consistent from lot to lot, making it easier to find recurring patterns.

A major issue was the subdivisions incompleteness when the 2009 aerial was taken, as noted in the above photograph. To complete vacant lots, projections were produced by looking at commonalities on adjacent blocks, roof square footage, landscaping, and driveways. As well as utilizing lower quality aerial photographs from 2011; these aerial photographs were difficult to use. During the site visit we paid special attention to such areas to ensure they were accurately represented; no major changes ensued.

During the site visit we were able to confirm vegetation types which were unclear in the aerial photos, identify permeable pavers, and note LID features. For example, we found curb cuts which allowed water to flow into vegetated strips, then hit a stone buffer surrounding the storm drain (PICTURE?. G-4). We classified such buffer zones as permeable pavement. We also discovered that residences within this subdivision have connected downspouts.

Lot



Neighborhood

3.4 GREENPOINT DEVELOPMENT

➤ SITE DESCRIPTION

Residential Units: 162 units

Size of Development: 35.4 acres

Density: 4.58 units/acre (Final EIR, 1993)

Initial Year of Development : 2003

Storm water Codes: Standard Urban Storm Water Management Plan

History

The GreenPoint development was first approved in 2003. Development stalled after the onset of the 2007 recession. In 2010, a new developer purchased the property (Council Meeting, 2011). The development is not yet complete. There currently 12 occupied units on the property.

GreenPoint is being built to surpass the minimum California building and energy requirements. The subdivision was awarded the 2012 Gold Nugget Award and is GreenPoint rated. The GreenPoint rating requires that the subdivision satisfy requirements in energy efficiency, resource conservation, indoor air quality, water conservation, community.

Design

GreenPoint is located on 26 acres of land. The projected build out includes 138 single family units, 24 apartments in 2 buildings, and a 2.16 acre neighborhood park. GreenPoint home single family home prices range from $302,990 to $443,990 (GreenPoint, 2012).

Demographics

GreenPoint is located in Southeast Santa Rosa. Its block group has a population of 3,569. The average household size is 3.05 persons per occupied unit. The census tract has a median household income ranging between $48,446 and $54,485. (U.S. Census, 2010)

(demo pie chart)

Stormwater Management

Beyond meeting SUSMP regulations, the development voluntarily implemented CALGreen measures. During a site visit, we observed a variety of stormwater management techniques: vegetated strips lined the streets; the community park doubled as a stormwater retention basin; further swales lined the park. Additionally, a major component of the site is an extended bioretention basin and a constructed wetland, which further improve infiltration and natural filtration of storm water runoff.

Image G-6

➤ TRANSLATING FROM SITE TO TOOL

Because the GreenPoint case study is currently under construction, it was necessary to find a recent aerial photograph for digitization. 2011 aerials proved to be poor resolution, but there were no preferable substitutes. Very few residences are in the aerial because this subdivision is not yet complete, making the digitization of existing units straightforward. To develop a viable projection of the site at full build out, we analyzed subdivision files, reviewed regulations, and monitored current construction.

Already constructed units allowed us to observe that all downspouts are connected, funneling water underground then onto the street, eventually flowing downhill into the bioretention area. The lots are landscaped with sparse vegetation, which will likely become dense over time, irrigated by high-efficiency spray irrigation. Newly planted trees were difficult to discern on the aerial, we were able to conduct a count during the site visit; the typical lot has two trees in the front yard, three on corner lots, and one or two in the rear yard. Also, our site visit allowed us to see that neighborhood vegetated strips are covered in mulch rather than top soil as we had previously believed.

Lot

Neighborhood

3.5 ONE PLANET DEVELOPMENT

➤ SITE DESCRIPTION

Residential Units: 1,892

Size of Development: 200 acres

Density: 8.5 units/acre

Initial Year of Development: Not yet built

Storm Water Codes: Standard Urban Storm Water Management Plan

History

One Planet will be a 200 acres of mixed-use, solar powered, zero waste community. In 2001, the plans for this community earned a LEED Platinum rating, the highest rating awarded by US Green Building Council. In 2008, it earned the Governor's Environmental and Economic Leadership Award for its land use planning. This is the highest environmental honor in California. One Planet is the first community in North America to be endorsed by the One Planet Communities program.

The development is scheduled to be built in three to six phases over a course of 12 to 20 years, depending on market condition. The project was approved by Rohnert Park's City Council and the residential phase was due to start in 2011-2012. Construction has not yet begun, however (Development Update, 2011).

Design

The development will house 5,000 people in a total of 1,892 homes. There will also be 77,000 square meter of office, commercial and retail space in the community (Demographic Profile). Lot sizes will range from 60 to 120 feet wide (One Planet Planned Development, 2010).

Because this is a mixed use development, it is not a true analog to the other three case study sites. The whole neighborhood includes many more services than the other residential-only neighborhoods. While we analyzed neighborhood data for this case study, it is most appropriate to compare the single family lots from the development to the single family lots from the other development.

Demographics

This site is not yet built, so demographic information is not available. In general, the town of Rohnert Park's median household income in 2000 was $51,942 and in 2007 it rose to $67,097 (Demographic Profile).

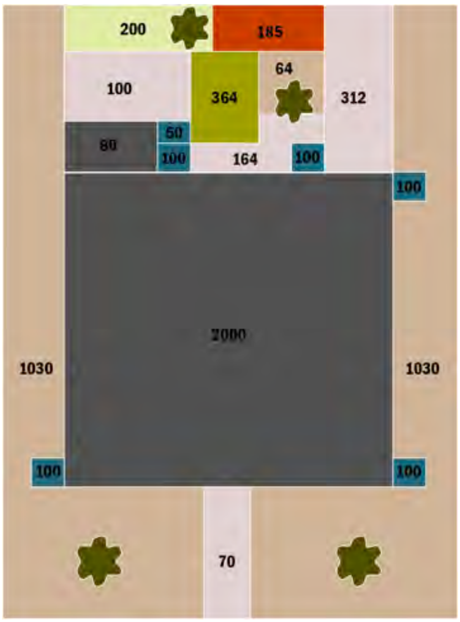
Stormwater Management

As a One Planet community, developers of One Planet strive to have a zero percent increase of water allocated to the site compared with the previous property owners (Developing a One Planet Community). Subsequently, storm water runoff regulations were devised in a manner in which will take full advantage of natural water. Rain barrels, cisterns, and underground water storage areas will enable rain water to be utilized for irrigation purposes in vegetated strips and public areas ([One Planet, 2009). Such measures also contribute to LEED certification. Within the sustainable storm water section, in order to achieve the highest point rating possible a site located within a semi-arid watershed is required to infiltrate, reuse, or evapotranspire 2.25 inches of water per year (Pilot Version, 2007). Other measures such as pervious pavers, vegetated strips, and bioretention areas will also contribute to an increased infiltration rate, decreased flow rate of storm water runoff, provide natural filtration of pollutants, and decrease the likelihood of flooding in surrounding areas.

This site has clay rich soils which limit the amount of runoff infiltrating the soils. Techniques for stormwater management include impervious surface controls, biofiltration swales and rain gardens, use of street trees with structural soil, and cisterns. The use of pervious surfaces for roads will be explored, when appropriate for vehicle use for places such as alley ways due to lower amounts of traffic. In places where biofiltration areas or rain gardens are not feasible due to space requirements underground infiltration galleries and cisterns will be put into place ([One Planet] Water Plan, 2009).

➤ TRANSLATING FROM SITE TO TOOL

Lot



Data for the lot analysis was constructed based on zoning codes and estimations. The lot dimensions as well as the distance between structures and boundaries were determined by the Rohnert Park Code of Ordinances, Title 17 Chapter 17.06 Article XV.A. Section 17.06.850 addresses Transect Zones, in particular T3 Suburban zones. These T3 Sub-Urban Zones include low density residential areas, near higher density zones, which include limited mixed use. This zone was used to better compare all four case study residential lot scales.

The width of the lot was chosen to be 70 feet. Section 17.06.850 states that lots can range from "sixty to one hundred twenty feet wide at the Principal Frontage" (Municipal Code of Rohnert Park, 2012). The lot line was chosen to be 70 feet based on regional precedent. The T3 Zone also requires a 20 foot minimum from the lot line to the principal building, which has been used in the lot scale image as well. The principal building is required to be at least 6 feet from the lot line if on a corner, and at least 5 feet from the opposite lot line if adjacent to a neighboring lot. The lot scale image includes a 6 foot space between the principal building and the lot line.

The driveway is located behind the house and is accessed through a back alley, per the subdivision design. The dimensions of the driveway were constructed as 12 feet wide, which is the minimum residential driveway width for the city of Rohnert Park (Streets and Roadway Design Standards, 2011).

The roof line is calculated based on a two-story house, which is the minimum building height for the principal building in T3 zones. This roof line dimension is also consistent to the other case study sites.

The landscape of the backyard was created from zoning requirements and regional precedent. The turf dimensions were based on Section 17.06.850 6c which states "Turf are is limited to thirty percent of the landscaped area within the Principal and Secondary Frontages" (Municipal Code of Rohnert Park, 2012). The turf area in the lot scale is roughly 10% of the landscaped area, which is under the 30% limitation.

The size of the rain garden, 200 square feet, is based on an average size from The Groundwater Foundation (Rain Gardens). The amount of rain barrels, in gallons, are based on the a rain barrel sizing guide (Rain Barrels and Cisterns) and the average rainfall intensity during a 1 hour rain fall event which happens 90% of rainfall events.

A large portion of the landscape consists of bark and sparse vegetation. The vegetation will be sparse for years after the development due to the growth rate. Bark was chosen as a dominate land coverage because that is a common drought resistant landscaping in the area.

Image of other one planet development

Neighborhood

(Final Development Plan, 2010)

Similar to the lot size description, the numbers for the neighborhood scale were constructed using zoning codes, and planned development plans from the City of Rohnert Park.

The amount of sidewalk was calculated based on the length of streets and the required width of the sidewalks. The width of the sidewalks was determined by the type of street; whether neighborhood, minor street, main street, etc. These totals were added together and the number is represented in the concrete sidewalk and driveway category. Driveways are assumed to be permeable pavers for residential, or included in the concrete area of civic parking structures. The curbs were determined based on the length of all the sidewalks based on the scaled image provided by the Development Zoning and Regulating Plan and is recorded in linear feet.

The street dimension was calculated by the length of the street and the width depending on the requirements, similar to the sidewalk classification; alley, neighborhood, minor street, main street, etc. This number is recorded in square feet and represents all streets in the One Planet neighborhood.

There is shown to be two civic parking areas which were calculated using the scaled image provided by the Final Development Plan. In the same plan there is an image which shows the parks spaces and the acreage of park and open space is already calculated; we used this value. The value for planter strips comes from the requirement of all sidewalks be lined with vegetated planter strips, or tree wells. Based on the required dimension and the length of the sidewalks, the square footage was constructed and recorded.

Finally, storm drain pipe sizes were not yet available for the GreenPoint case study due to its current stage of development. The Municipal Services Plan offers the location of such pipes for each of the phases; utilizing this plan we were able to measure the pipes and deduce lengths based upon the provided scale of one inch for every two-hundred-fifty feet, resulting with a total length of 22,844 feet. The plan also noted an average pipe diameter of 48 inches.

Add photo or graphic

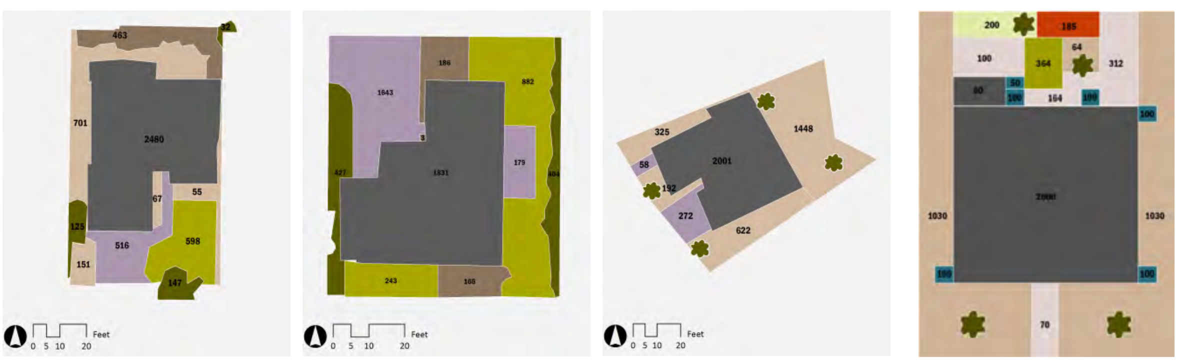
4 RESULTS

After translating the case study sites into GIS and quantifying water infrastructure, we evaluated the lots and neighborhoods using the *Integrated Water and Land Smart Planning Tool.*

Though the lots in each case study were slightly different sizes, comparing across the case study sites was possible in the context of evaluating the consumption metrics per household. Comparing the neighborhoods, on the other hand, proved to be more challenging. Not only were the neighborhoods vastly different sizes, but they were also programmatically different. In particular, the One Planet neighborhood with commercial and office space was not truly analogous to the other neighborhoods. As a result, only the residential neighborhoods—Traditional, SUSMP, and GreenPoint—are compared against one another in the neighborhood analysis.

4.1 LOTS

TRADITIONAL SUSMP GREENPOINT ONE PLANET



➤ OVERVIEW

For each case study, we identified one lot with characteristics that are representative of the other single family lots within the same subdivision. We entered the landcover and site water infrastructure information for each sample lot into the tool and compared the output metrics.

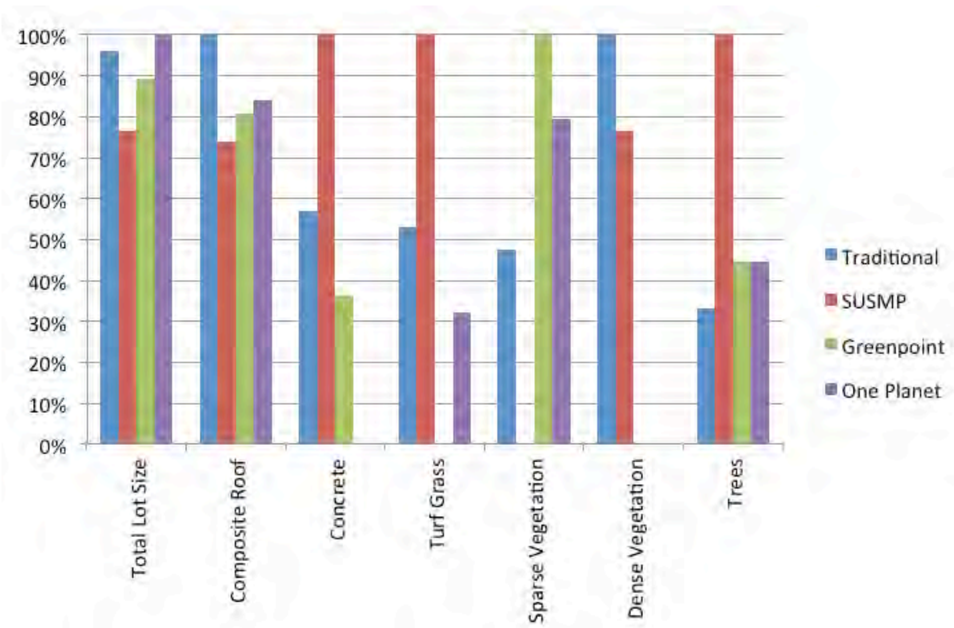
All formulas and assumptions are detailed in Appendix 4.

➤ INPUTS

While we built the tool to accommodate a wide array of different land cover types and water infrastructure options, we observed more limited set of land covers in our typical lots. Following are the land covers observed in each case study lot:

	Traditional	SUSMP	GreenPoint	One Planet
Total Lot Size	5,285	4,217	4,918	5,509
Composite Roof	2,480	1,831	2,001	2,080
Concrete	516	907	330	
Permeable Pavers				828
Turf Grass	598	1,125		364
Cultivated Garden				185
Sparse Vegetation	1,228		2,587	2,052
Dense Vegetation	463	354		
Trees (count)	3	9	4	4

Following is the same data, visualized on a normalized scale:



From the chart, it is easier to see that SUSMP is the smallest lot with the smallest roofline, but has the largest amount of concrete and turf grass. In comparison, GreenPoint and One Planet have little turf grass. In fact, the GreenPoint sample lot has no turf grass at all.

GreenPoint and Traditional each have substantial amounts of sparse vegetation. This is, in part, because each development uses drought-sensitive landscaping. It is also because the vegetation is not mature yet; one of the limitations of this method is that is difficult to differentiate planting style and age of vegetation.

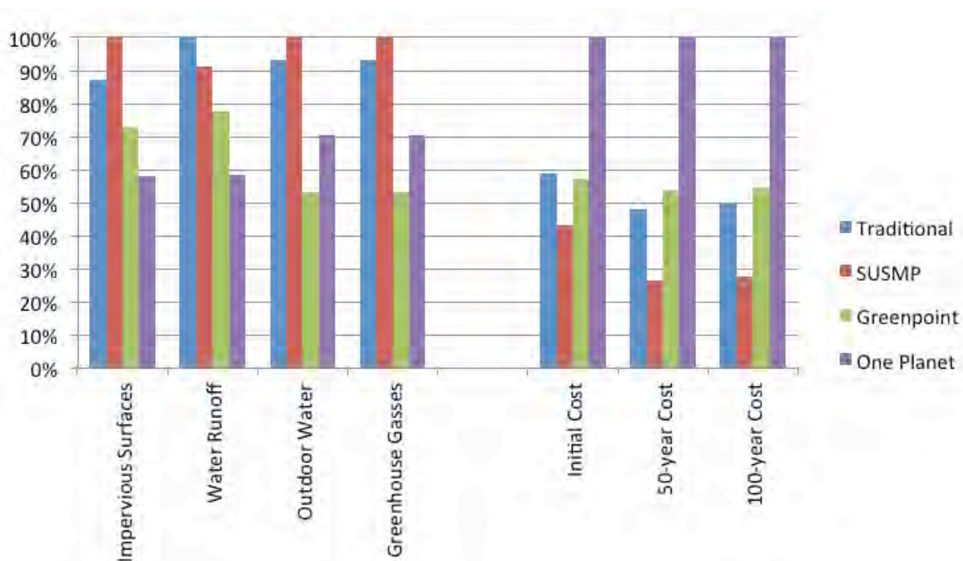
Finally, SUSMP has many more trees than the other developments.

➤ OUTPUTS

The different input values from the lots are reflected in similarly different output values.

	Traditional	SUSMP	GreenPoint	One Planet
Total lot size	5589	4712	4918	5509
Percent impervious land cover	54%	58%	47%	38%
Peak monthly water runoff from impervious cover (gal)	13,943	12,742	10,848	8,184
Peak monthly outdoor water consumption (gal)	3,738	4,291	1,874	2,363
Peak monthly CO2 emissions from outdoor water use (lbs)	3.8	4.4	1.9	2.7
Cost of program				
Initial cost	$23,876	$17,458	$23,716	$41,727
50 year cost	$92,510	$56,368	$100,233	$193,838
100 year cost	$174,578	$108,780	$187,000	$357,169

Again, variation between the lots for each output metric can be visualized simultaneously on a normalized table:



The SUSMP lot has the most amount of impervious surfaces, followed by Traditional. While the Traditional lot has approximately half as much concrete as the SUSMP lot, the larger square footage of its roof contributes to site imperviousness.

As a result of the total impervious surfaces, the monthly water runoff from Traditional is the highest, followed close behind by SUSMP.

Because of its large turf grass areas, SUSMP has the highest monthly outdoor water use, followed by Traditional. GreenPoint's outdoor water use is the lowest because it has no turf grass or other high water-use outdoor planting. The One Planet lot has both turf grass and a cultivated vegetable garden, which pushes its use higher.

Because of its relatively high outdoor water use, SUSMP also has the highest GHG production. Traditional is close behind SUSMP, followed by GreenPoint and One Planet.

Based on the cost metrics of the tool (cost of supplies, labor and replacement), the most expensive home to develop initially and maintain over the long term is One Planet. With more expensive permeable pavers, rain barrels which require occasional replacement, and annual gardens, it requires more money to maintain the One Planet home. In addition, it is on the largest lot, so the there is a larger area to build and maintain.

The least expensive lot to build and maintain over time is SUSMP. Not only is it the smallest lot, but its simple outdoor design—relatively inexpensive concrete and turf grass —require less upfront money per lot.

➤ SENSITIVITY TESTING

The values used to calculate tool outputs are the best available information. Over time, there will be changes in the market place and local conditions that impact costs and water consumption, however. To assess the vulnerability of the tool to variation to market and environmental variations, we examined two basic scenarios: (1) Concrete costs decrease by 20%; (2) Plants consume 10% more water. We selected these scenarios because they represent extreme cases.

Scenario 1. Concrete costs decrease by 20%

Recent reports indicate that concrete costs have risen 3% in the past year (Construction Economics, 2012), but we chose to assess the impact of decreased concrete costs because this should privilege status quo development styles. This sensitivity testing analyzes how much the total costs of the full lot program changes if concrete prices drop by 20%.

The following chart summarizes the existing cost metrics and the change in cost if concrete prices drop by 20%.

	Traditional	SUSMP	GreenPoint	One Planet
Cost of program, standard concrete cost				
Initial cost	$23,876	$17,458	$23,716	$41,727
50 year cost	$92,510	$56,368	$100,233	$193,838
100 year cost	$174,578	$108,780	$187,000	$357,169
Cost of program, concrete down 20%				
Initial cost	$23,173 (-1.0%)	$16,222 (-1.1%)	$23,267 (-1.0%)	$41,727 (0%)
50 year cost	$91,104 (-1.0%)	$53,898 (-1.0%)	$99,334 (-1.0%)	$193,838 (0%)
100 year cost	$171,767 (-1.0%)	$103,838 (-1.0%)	$185,202 (-1.0%)	$357,169 (0%)

With a 20% decrease in the price of concrete, the total program cost only declines by about 1% for each lot (One Planet showed no change because there is no concrete on the lot). Because concrete only represents one of the costs folded into the total program cost at Traditional, SUSMP and GreenPoint, a large decrease in the price of concrete only had minor impacts on the full cost calculations. This indicates that the tool results will be robust to normal price variability.

Scenario 2. Plants consume 10% more water

Plant water consumption is very sensitive to local environmental conditions. In the tool, we assumed that all plants were exposed to equal conditions. In reality, some places are sunny and windy, while some are sheltered and damp. In addition, climactic variability may influence consumption. This sensitivity test analyzes how much the total water consumption will change if all plants are exposed to a hotter, drier environment, and consequently consume 10% more water.

The following chart summarizes the existing water consumption and the change in each lot's water consumption if all plants consume 10% more water.

	Traditional	SUSMP	GreenPoint	One Planet
Outdoor water consumption, standard				
July water consumption	3738	4291	1874	2363
Outdoor water consumption, plants consume 10% more				
July water consumption	4112 (+10%)	4720(+10%)	2061 (+10%)	2653 (+12%)

Since this change was applied across all plants, in the Traditional, SUSMP and GreenPoint lots the total water use increased 10%. The change in the One Planet lot is higher than 10%, though. This is because part of the monthly water landscaping needs are met with local water storage. As the water budget of the plants goes up, but the volume of the rain barrels does not change, the lot consumes more municipal water.

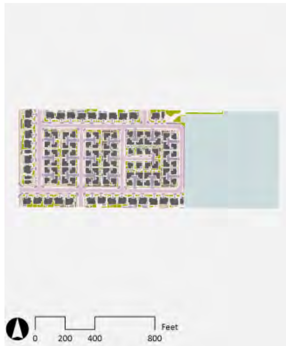
This test on outdoor water use demonstrates that the model is very sensitive to changes in local environmental conditions. It will be necessary for users of the tool to carefully examine the Water Consumption tab within the Excel tool and consider how the default values should be modified to match local conditions.

For this reason, too, comparisons across sites in different microclimates should be approached with caution.

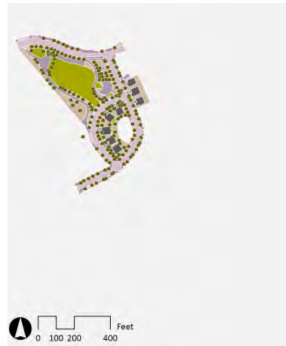
4.2 NEIGHBORHOODS

TRADITIONAL

SUSMP



GREENPOINT



ONE PLANET

➤ OVERVIEW

Unlike the lots, which are similarly sized, the neighborhoods are vastly different sizes. The neighborhoods also have different proportions of single-family and multi-family units. The One Planet development even includes a commercial core and office space.

Comparing among the developments is difficult because of their variation in size, number of units, and differences in land uses . As a result, after assessing the input values, we chose to limit comparisons among the neighborhoods to those which are exclusively residential. To compare these developments we calculated an average resource use per acre.

➤ INPUTS

		Traditional	SUSUMP	GreenPoint	One Planet
Total neighborhood size	sq ft	2,453,620	752,184	1,304,277	8,712,000
Total number of single-family Homes	count	224	88	138	743
Total number of multi-family homes/apartments	count		62	24	951
Total dwelling units	count	224	150	162	1694
Density	du/ac	4.0	8.7	5.4	8.5
Lot Landcover					
Concrete	sq ft	261,222	93,909	50,219	
Pavers, brick or nautral stone	sq ft	29,577	3,047		
Permeable pavement - pavers	sq ft	22,699	364		165,600
Deck	sq ft	16,190			
Turf grass	sq ft	314,462	64,405	527	72,800
Artificial turf grass	sq ft	425			
Cultivated flower or vegetable garden	sq ft	3,783			37,000
Sparse irrigated vegetation	sq ft	144,322	50,704	314,172	410,400
Dense irrigated vegetation	sq ft	87,551	54,850		
Pool/Fountain/Hot Tub	sq ft	2,691			
Pond	sq ft	165			
Existing trees (canopy)	sq ft	388,209	6,136	7,081	
Existing trees (count)	count	1,587	227	872	800
Composition Roof	sq ft	780,087	220,978	259,664	416,000
Lot Water Infrastructure					
Rain barrels	gal				110,000
Downspout disconnection	%	100			
Rain garden	sq ft				40,000
Irrigation controllers	1 or 0				1
Neighborhood transportation infrastructure (hardscape)					
Street, asphalt	sq ft	425,993	117,559	186,119	1,651,200
Curbs and Gutters, concrete	sq ft	24,161	7,395	13,919	31,840
Sidewalk, concrete	sq ft	110,296	54,860	95,219	315,920
Parking Lot, asphalt	sq ft			16,809	90,000
Neighborhood water infrastructure					
Corrugated Metal Pipe (CMP)					
15 in	lf	2,528	551	474	
18 in	lf	575	1,220	1,380	

24 in	lf		135	291	
30 in	lf		250	442	
36 in	lf			423	
42 in	lf			691	
48 in	lf				22,844
Reinforced Concrete Pipe (RCP)					
21 in	lf	119			
24 in	lf	19			
27 in	lf	523			
30 in	lf	760			
36 in	lf	304			
46 in	lf	340			
54 in	lf	700			
96 in	lf			31	
Bioswales	sq ft	9,807	31,103	34,939	813,520
Managed open space	sq ft	244,967	6,760	145,725	422,532
Naturalized open space	sq ft	38,486	423,555	61,399	766,656

While there are many differences among the input values for the developments, one of the largest differences relates to the amount of open space within the development. The following table summarizes the open space as a proportion of the total development:

	Traditional	SUSMP	GreenPoint	One Planet
Managed open space (percent of total development area)	10%	1.0%	11%	4.9%
Naturalized open space (percent of total development area)	1.6%	56%	4.7%	8.8%

As a percent of total area, SUSMP has by far the largest naturalized open space at 56%. Its managed open space area is comparatively very small. Traditional and GreenPoint are 10% and 11% managed open space, while SUSMP is approximately 1%. The large naturalized open space at the SUSMP development is likely due to the development's contingent approval by the Santa Rosa Planning Commission on no net increase in runoff.

While the neighborhood open space is different, the neighborhoods all had very similar amounts of neighborhood transportation infrastructure:

	Traditional	SUSMP	GreenPoint	One Planet
Neighborhood asphalt and concrete (percent of total development area)	23%	24%	24%	24%

➤ OUTPUTS

Because the One Planet neighborhood was sufficiently different from the others with its mix of land uses, after observing the input values we chose to drop the case from the neighborhood comparisons.

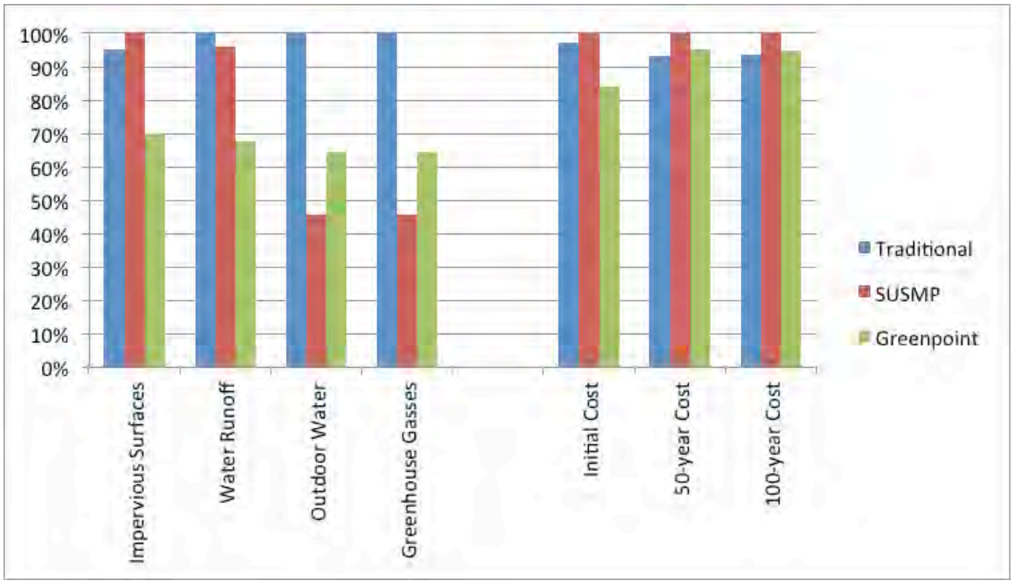
Comparing the output values from Traditional, SUSMP and GreenPoint developments is still challenging, however. Traditional is almost twice the land area of GreenPoint.

		Traditional	SUSMP	GreenPoint
Total land area	sq.ft	2,453,620	752,184	1,304,277
Total impervious land cover (residential + community infrastructure)	sq.ft	1,684,603	541,456	657,234
Percent impervious land cover (of whole development)	percent	69%	72%	50%
Peak monthly water runoff from impervious cover	gal	7,765,232	2,287,181	2,797,296
Peak monthly outdoor water consumption	gal	2,435,093	342,715	837,076
Peak monthly CO2 emissions (from outdoor water use)	lbs	2,485	350	854
Cost of program				
Initial cost	dollars	$12,398,823	$3,917,678	$5,702,763
50 year cost	dollars	$35,506,782	$11,678,161	$19,273,060

To compare the developments, we chose to calculate the resource consumptions per acre:

		Traditional	SUSUMP	GreenPoint
Percent impervious land cover	acre/acre	0.69	0.72	0.50
Peak monthly water runoff from impervious cover	acre-foot/acre	0.42	0.41	0.29
Peak monthly outdoor water consumption	acre-foot/acre	0.13	0.06	0.09
Peak monthly CO2 emissions (from outdoor water use)	lbs/acre	44.11	20.25	28.53
Cost of program				
Initial cost	dollars/acre	$220,121	$226,878	$190,460
50 year cost	dollars/acre	$630,365	$676,298	$643,678
100 year cost	dollars/acre	$1,200,184	$1,283,738	$1,217,347

Visualized simultaneously we can see trends across the neighborhoods more easily:



This chart demonstrates that, on a per acre basis, the results are fairly different than the lot-scale analysis. After folding in neighborhood infrastructure, SUSMP has the lowest outdoor water and GHG impacts. SUSMPs low outdoor water needs are because, as a development, it has very little managed open space.

Notably, while the individual lot costs are different, as a development the costs are fairly similar over time. This is because the cost of the neighborhood infrastructure is sufficiently large that differences in specific lot-by-lot land cover choices are relatively small.

GreenPoint initially has a slightly lower implementation cost, though. This is because summed across all of the lots, GreenPoint has fewer hard surfaces to construct. To some degree this was evident at the lot level —GreenPoint has fewer impervious surfaces per lot — but it is also because the density of the development is lower (i.e., there are few lots to construct per acre).

4.3 BEYOND THE CASE STUDIES: CITY, COUNTY, AND WATERSHED

➤ OVERVIEW

Beyond the neighborhood, the results of the tool have not been ground-tested or compared with case studies. This scale of analysis is simply for visioning purposes and to allow users to create and test alternative development scenarios.

In this report we will consider how any of the neighborhood development choices might scale if they were implemented across the whole watershed. It is also possible for a user to break down the larger areas into many different types of neighborhoods. We are coarsely applying the same neighborhood type across an entire watershed, but this is only one possible way to use the tool for visioning purposes.

➤ INPUTS

We summed all of the land that is zoned as residential in the Russian River watershed. This watershed intersects all of the case study sites. It also includes the cities of Santa Rosa and Rohnert Park, all of Sonoma County, and portions of Mendocino and Lake County. All of the residential land in the Russian River watershed is shown below in orange. The total residential land is approximately 194,555 acres.

➤ OUTPUTS

		Traditional	SUSUMP	GreenPoint
Percent impervious land cover (of whole development)	acre	133,577	140,049	98,038
Peak monthly water runoff from impervious cover	acre-foot	82,311	79,084	55,780
Peak monthly outdoor water consumption	acre-foot	25,812	11,636	14,036
Peak monthly CO2 emissions (from outdoor water use)	lbs	8,582,279	3,869,038	4,666,898
Cost of program				
Initial cost	dollars	$42,850,104,221	$43,549,774,745	$37,040,550,806
50 year cost	dollars	$122,665,110,757	$122,370,506,917	$115,344,708,703
100 year cost	dollars	$233,526,355,886	$231,934,660,441	$217,451,259,182

Comparing one development style across the whole of the Russian River watershed is a simple method of demonstrating that different development styles have cumulative impacts. While the costs of the development forms do not vary substantially (approximately a 7-8% difference in the range of values), some of the water-related metrics are quite different. For example, if the whole watershed were developed in the style of GreenPoint, there may be as much as a 30% decrease in the total volume of stormwater runoff.

While these numbers, as absolutes, should be approached with skepticism, in general it is significant that with very little difference in the dollar cost of any development program, there is potential for substantial positive changes in the metrics which gauge impacts to water quality, flooding, and supply reliability.

Add photo or graphics

5 CONCLUSIONS

(TEXTBOX-QOUTE # 1)

This study is the beginning of quantifying cumulative impacts of local development choices over space and time. Results from applying the tool to the case studies indicates that there may be potential for some cost savings and there is certainly potential for strong positive water quality, flooding and supply reliability impacts from smart land use choices.

As the tool is further developed, the differences in the monetary costs of the different development programs will become even more clear. Yet, even with the existing data we can conclude that projects with reduced hardscapes, smaller building footprints and less elaborate infrastructure requirements are more likely to yield the most economical designs.

5.1 ACTIONS

After analyzing the case studies with the tool, we recommend the following actions.

➤ REDUCE HARDSCAPE

(TEXTBOX #2)

Hardscaping, such as asphalt and concrete, is expensive to build and maintain. By decreasing the footprint of hardscaping, projects save money while simultaneously reducing water runoff. In general, substituting traditional materials for more porous, LID-friendly materials is less important than reducing total square footage.

In addition, common building materials can be intelligently sited to further decrease impacts on water resources. For example, if a small concrete driveway is graded to drain into a permeable surface, the impacts will be even smaller than if its graded to drain into the street.

➤ MANAGE RUNOFF FROM ROOFS

(PICTURE 5-1)

Large roofs on small properties can dramatically increase the percent imperviousness of a site. Unfortunately, stormwater capture methods to mitigate for large roofs (e.g., rain barrels) are not as effective as avoiding impacts. When possible, it is best to have a small building footprint and a small roof line.

When this is not possible, even small changes in traditional designs can have big impacts. Depending on the local soil and slope conditions, disconnecting downspouts and adding french drains can be simple methods of reducing or slowing water runoff. In some places, rain gardens specifically designed to capture roof water can be a big benefit, too.

➤ PLAN FOR WATER EFFICIENT LANDSCAPES

(PICTURE 5-3)

Many water runoff and consumption challenges can be avoided by smart planning before development. By minimizing new hardscape and creatively draining and diverting water, it is possible to create a low-cost development that is also low-impact.

5.2 CHALLENGES AND OPPORTUNITIES

➤ DEVELOPING FULL COST METRICS

This tool relies on the prices of labor and supplies for assessing costs. As a result, the tool clearly shows the OnePlanet lot is more expensive to build than the SUSMP lot. Yet, the tool also reveals that the water runoff, water consumption, and greenhouse gas emissions are lower for OnePlanet than SUSMP.

While supply, labor and replacement costs are useful, developing a more comprehensive set of cost metrics is essential to adequately understanding the true costs of choosing one development alternative than another. Furthermore, dividing up those full costs into who bears the cost may help reveal how short-term cost savings at the lot or neighborhood level lead to onerous, long term expenses carried by the municipality.

At present, there are gaps in data on secondary costs and externalities like green house gas production. Additionally, assigning who bears the cost burden of a piece of infrastructure can be challenging. Nonetheless, further developing component costs and who bears the cost burden will provide a new window into development decisions.

➤ ALIGNING INCENTIVES

Despite the potential of green infrastructure to reduce lifecycle costs over traditional infrastructure choices, there are many barriers to uptake. One barrier may be that planning for water efficient landscapes is less familiar. An additional barrier may be that the cost of infrastructure maintenance is often not shouldered by the same entity which initially installs the infrastructure. Since the benefits of green infrastructure often accrue over the long term, not at implementation, the incentive for developers to explore alternative infrastructure options is low. Further developing full cost metrics may help reveal the urgency of managing lifecycle costs at the initiation of a project.

➤ LINKING LID AND FLOOD WATER MANAGEMENT

At present, implementing LID techniques has no influence on sizing the conventional storm water system required for a development. Although LID components impact volumes and rates of stormwater runoff, LID infrastructure is typically sized for a 24 hour rainfall event, while stormwater systems are sized for 100 year flood events. In other words, storm water systems are designed to handle less frequent, but intense rainfall events, while Low Impact Development techniques are designed to handle more frequent, but less intense rainfall events.

Resizing stormwater pipes to account for upstream green infrastructure has the potential for measurable cost savings. Further study of the watershed-wide impacts of LID implementation will be required, but the benefits of aggregating small changes should not be overlooked.

➤ TRADING OFF HARDSCAPE AND DENSITY

One of the most challenging problems with water-smart development is that, within a development, stormwater runoff increases with more impervious surfaces. Yet, denser developments typically necessitate more impervious surfaces.

Initially, it may seem as though this tool advocates against dense development. This is not the case. Instead, this tool highlights the need for dense development to strive to reduce impervious surfaces. While, in the suburbs, reduced imperviousness may be accomplished by resizing driveways, in more dense environments it is likely necessary to introduce newer, porous materials.

The fact that density is not favored by the tool reveals a gap in the cost metrics for new developments. With basic real estate calculations it may be possible to test which LID components make sense, given the number of units for sale and estimated sale prices.

5.3 NEXT STEPS

This tool was designed to be open source and accessible. Anyone can test, criticize, modify, and re-distribute the tool. Following are areas of future research we have identified which are necessary to increase the robustness of the tool.

1. **Distribute and test** the "Integrated Water and Land Smart Planning Tool at local planning, building and public works departments. When the model was developed it was anticipated that it would be useful to local government agencies when evaluating and conditioning development proposals. Its application to new development and retrofit projects has the potential to positively impact water quality. Feedback on the application of the model by local government agencies will assist in refining the model and expanding its use.

   The model will also be useful to development project designers - architects, landscape architects and engineers – as they prepare plans for review by public agencies, as well as the individual homeowner who may wish to evaluate the benefit of water-smart components on a property. Because these users represent a wide range of technical expertise, testing of these applications by actual users may suggest modifications to enhance "user-friendly" aspects and, therefore, greater use.

2. **Validate tool results** against recorded outdoor water use and cost data.
3. **Conduct case studies of higher density residential and mixed-use urban projects**. We initially studied suburban development because of it is a dominant housing typology now and will continue to be in the future. Yet, with legislation like SB 375, there will likely be an increasing amount of more densely settled, mixed-use development.
4. **Conduct case studies at broader spatial levels**, including the city, county and watershed. What are methods for evaluating the accuracy of tool results?
5. **Improve cost calculations** by folding improved lifecycle costs and externalities into per unit valuations. Averted costs may also be a useful addition (for example, growing vegetables on-site likely has a positive economic feedback).

6 APPENDICES

6.1 TOOL REVIEW TABLE

Toolkit Name	Green Infrastructure Valuation Toolkit	National Stormwater Management Calculator	LID Runoff Volume Calculator
Type	Calculator	Calculator	Calculator
Toolkit Type	Excel-based tool	Web-based tool	Excel-based tool
Year Published/Last Updated	2010	2010	
Location	England	Chicago, IL	California
Creator	Collaboration of several businesses and nonprofits	Center for Neighborhood Technology	Los Angeles County, Department of Public Works
Description	The Green Infrastructure Valuation Toolkit includes both a user guide and an Excel-based calculator. The calculator consists of a set of individual spreadsheet-based tools to assess the value of green assets or projects across a wide range of potential areas of benefit - such as climate change, health, or property values. Wherever possible results are given in monetary terms."	The National Green Values™ Calculator is a tool for quickly comparing the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), to conventional stormwater practices.	The LID Calculator allows the site designer/engineer to calculate runoff rates and volumes from the water quality storm.
Additional Details	The User Guide sets out the evidence base and rationale supporting each of the assessment tools, and provides case studies giving practical examples of how the Toolkit can be applied and the results presented. The Guide also discusses the strengths and weaknesses of the Toolkit and highlights areas where further research or development work is needed.	The GVC is designed to take you step-by-step through a process of (1) determining the average precipitation at your site, choosing a stormwater runoff volume reduction goal, (2) defining the impervious areas of your site under a conventional development scheme, and then choosing from a range of Green Infrastructure Best Management Practices (BMPs) to find the combination that meets the necessary runoff volume reduction goal in a cost-effective way. They also have a PDF of "Calculator methodology" at http://greenvalues.cnt.org/calculator/downloads/methodology.pdf	
Tool Scope		National	
Inputs		Lot information (zip code, annual rainfall, storm rainfall, lot size, soil type), land cover, runoff reduction goal, green improvements, cost parameters, impervious area	Area, soil type, rainfall amount, flow path length, flow path slope, proportion impervious,
Outputs	Monetary, Quantitative and Qualitative (outputs vary)	req. volume capture, runoff, construction costs, maintenance costs, life cycle costs, other benefits (carbon dioxide sequestration, reduction in air pollutants, reduced energy use)	Intensity, Undeveloped runoff coefficient, developed runoff coefficient, Tc Value, 24-hour Runoff Volume
Website	http://www.greeninfrastructurenw.co.uk/html/index.php?page=projects&GreenInfrastructureValuationToolkit=true	http://greenvalues.cnt.org/national/calculator.php	http://dpw.lacounty.gov/wmd/dsp_LowImpactDevelopment.cfm

Toolkit Name	BMP Sizing Calculators	LID BMP Sizing Calculator for Kitsap County	Green Infrastructure Whole-Life Cost Tool
Type	Calculator	Calculator	Calculator
Toolkit Type	Excel-based tool	Excel-based tool	Excel-based tool
Year Published/Last Updated	2011		
Location	San Francisco	Washington	Chesapeake Bay Watershed
Creator	San Francisco, Public Utilities Commission	Home Builders Association of Kitsap County - Low Impact Development	Water Environment Research Foundation
Description	The LID Calculator allows the site designer/engineer to characterize existing surfaces, and choose from a suite of green infrastructure strategies to reduce runoff rates and volumes.	This spreadsheet tool guides the user through selecting and sizing pre-designed stormwater management best management practices (BMPs) in Kitsap County, Washington. The 8-6-10 versions provides a "Project Information" box at the top of the sheets and has added some clarification on the minimum aggregate depth for permeable pavement surfaces.	The whole life cost (WLC) models are a set of spreadsheet tools that have been developed to facilitate automation of a whole life costing approach. The models allow users to systematically identify and combine capital costs and ongoing maintenance expenditures in order to estimate whole life costs. Costing Tools for: Cisterns, Curb-contained Bioretention, Extended Detention Basins, Green Roofs, In-curb Planters, Permeable Pavement, Rain Gardens, Retention Ponds, & Swales
Additional Details	New and redevelopment projects built in San Francisco can create increases in stormwater flows that can affect San Francisco's wet weather capacity and permit compliance. SFPUC conducts project review to ensure that new and redevelopment projects reduce their impacts on the wastewater system. This review process applies to all projects disturbing 5,000 square feet or more of the ground surface, including emerging communities like Hunters Point Shipyard, Treasure Island, Visitacion Valley, and Executive Park.		These spreadsheets were developed under two efforts. Under the first effort, extended detention basin, retention pond, swale and permeable pavement spreadsheets were developed in a joint project between the Water Environment Research Foundation (WERF) and United Kingdom Water Industry Research (UKWIR). The second effort included collaboration between the WERF and the U.S. Environmental Protection Agency to expand the original suite of tools to include bioretention, green roofs, and cisterns.
Tool Scope			National
Inputs	Area, soil type, rainfall amount, proportion impervious,		
Outputs	Undeveloped runoff coefficient, developed runoff coefficient, runoff volume and rate.		Capital costs, maintenance costs, cost summary, whole life costs, NPV graph
Website	http://sfwater.org/index.aspx?page=446http://sfwater.org/index.aspx?page=446	http://www.kitsaphba.org/LID/resources.html	www.region9wv.com/bay/LIDtools.html

Toolkit Name	LID Versus Conventional Development: Literature Review of Developer-Related Costs and Profit Margins	Low Impact Development at the Local Level: Developers' Experiences and City and County Support	The Economics of Low-Impact Development: A Literature Review
Type	Report	Report	Report
Toolkit Type			
Year Published/Last Updated	Dec-09	Feb-09	Nov-07
Location		Oregon	Oregon
Creator	Auckland Regional Council	ECONorthwest	ECONorthwest
Description		This part of the analysis looked beyond the study site and relied on descriptions of LID case studies from across the U.S. This report describes the second part of the analysis, which focused on two aspects of LID adoption at the local level: the experiences that developers have had with LID, and actions that local jurisdictions can take to increase LID use.	Literature review of the methods, data sources economists use to do cost-benefits analysis of LID and conventional stormwater controls.
Additional Details		In this report, ECONorthwest describes the second part of a two-part study organized by the Rock Creek Sustainability Initiative (RSCI). (1) Summary of the major challenges that can inhibit developers' use of LID. (2) Results of economic analyses of developments that included LID vs. conventional stormwater controls. Under the conditions described in these studies, developments with LID can cost less than comparable developments with conventional stormwater controls, can sell for more, or both. (3) Describes actions taken by local jurisdictions that increase LID adoption, summarizes of some of the steps taken by local jurisdictions that modify building and inspection codes to include LID, and then list the types of incentives that local jurisdictions use to promote LID. (4) Actions that the RSCI partners and stakeholders can take to increase LID adoption in their jurisdictions.	This literature review has three objectives. (1) Describe briefly the methods economists use when measuring the costs and benefits of LID and conventional stormwater controls. This information provides the reader with a context for the economic descriptions of costs and benefits that follow. (2) Summarize the literature that identifies and measures the economic costs and benefits of managing stormwater using LID, or that compares costs or benefits, or both, between LID and conventional controls. (3) Organize and present this information in a way that non-economist municipal officials, stormwater managers, ratepayer stakeholders and others can use as they consider and deliberate stormwater-management plans.
Tool Scope			
Inputs	None	None	None
Outputs	None	None	None
Website		http://econw.com/our-work/publications/low-impact-development-at-the-local-level-developers-experiences-and-city-a/	http://econw.com/our-work/publications/the-economics-of-low-impact-development-a-literature-review/

Toolkit Name	Low Impact Development, An Economic Fact Sheet	Low-Impact Development Hydrologic Analysis	Cost-Estimating Tools for Low-Impact Development Best Management Practices: Challenges, Limitations, and Implications
Type	Report	Report	Report
Toolkit Type		Guide	
Year Published/Last Updated		1999	Mar-11
Location		Maryland	
Creator	NC State University Cooperative Extension	Prince George's County, Maryland: Department of Environmental Resources	American Society of Civil Engineers
Description	The purpose of this factsheet is to provide basic economic information on Low Impact Development. This simplified overview of a complicated topic is intended to help citizens, developers, and policy-makers have an informed discussion about the costs, benefits, and trade-offs of LID in their community.	Hydrologic analysis of LID	Tools were developed for estimating costs of vegetative roofs, rainwater catchment systems, and bioretention facilities. These tools provide a detailed framework to facilitate cost estimation for capital costs, operation and maintenance costs, and life-cycle net present value.
Additional Details			**[MUST PURCHASE PDF]** The tools can provide users with planning-level cost estimates and serve as a format for cost-reporting for past, current, and future projects. Very little cost data was available in the public forum, and prolific inconsistencies of supporting details were found in the available cost data. To address this, design assumptions were established for each facility type and professionally prepared cost estimates based on these design assumptions were used. Electives in design, such as plant selection and media depth, also greatly affected costs. To make the user aware of these effects, the model separates each option into line items that can be elected or excluded as appropriate. To facilitate collecting future cost data, best management practice (BMP) designers and builders should use these tools to record actual costs and report them to a clearinghouse such as the BMP Database.
Tool Scope			
Inputs	None		None
Outputs	None		None
Website	http://www.ces.ncsu.edu/depts/agecon/WECO/nemo/documents/WECO_LID_econ_factsheet.pdf		http://ascelibrary.org/iro/resource/1/jidedh/v137/i3/p183_s1?isAuthorized=no

Toolkit Name	A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds	Integrating Valuation Methods to Recognize Green Infrastructure's Multiple Benefits	Portland's Green Infrastructure: Quantifying the Health, Energy and Community Livability Benefits
Type	Report	Report	Report
Toolkit Type			
Year Published/Last Updated	2009		2010
Location			Portland
Creator	City of Philadelphia Water Department by Stratus Consulting	Center for Neighborhood Technology, University of Illinois at Urbana-Champaign, Low Impact Development Center, ECO Northwest, Drexel University, Forest Trends Association, US Forest Service, Northern Research Station, Green Roofs for Healthy Cities, University of Chicago	City of Portland, Bureau of Environmental Services
Description	This report compares the benefits provided by a green infrastructure approach to CSO control to the benefits provided by a traditional tunnel approach. The report monetizes a range of environmental, social, and public health benefits.		This report quantifies the positive effects of using LID including Energy use and reduction in GHG emissions. (See section 4)
Additional Details			
Tool Scope			
Inputs	None	None	None
Outputs	None	None	None
Website	http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_philadelphia_bottomline.pdf	http://www.igoplat.com/repository/CNT-LID-paper.pdf	http://www.portlandonline.com/bes/index.cfm?c=52055&a=298042

Toolkit Name	**Low-Impact Development Strategies and Tools for Local Governments -- Comprehensive Cost Estimating Worksheet**
Type	Report
Toolkit Type	Worksheet
Year Published/Last Updated	
Location	
Creator	LMI Government Consulting
Description	"Comprehensive Cost Estimating Worksheet" (Page 20) calculates (1) Estimate Life-Cycle Cost, (2) Effectiveness Factor, and (3) Secondary Benefits Factor
Additional Details	**Life-Cycle Cost.** Insert cost data for each phase and component of the project using the best available information. The table presents the typical cost components for each phase of the project. Considering all the components and entering the net present value for future investments using an appropriate discount factor are critical. As a simplified approach, consider all dollars in current year value, negating estimates of price escalation or discounting. Add the costs up from each phase to determine the LCCs. **Effectiveness Factor.** This section of the worksheet is a simple way to apply the concept of cost-effectiveness to the decision-making process and does not require the use of complex calculations. Specify the specific goals (or minimum requirements) of the project, adding rows to the worksheet if necessary. Use knowledge of conventional stormwater management and LID to determine whether the project will meet, exceed, or fall short of the objective. Enter the corresponding number into the appropriate field. The total of these numbers will provide an effectiveness factor. Each alternative must have the same objectives listed in this section of the sheet. Since these numbers simply represent a concept, they must be entered for each alternative to be comparable. **Secondary Benefits Factor.** A LID project often offers secondary benefits, such as increased green space, protected habitat, and other amenities. The secondary benefits portion of Table 3-2 lists a number of these, merely asking whether a particular project alternative offers them or not. The sum of "yes" answers represents a summation for these secondary effectiveness factors. In a few cases, it may be possible to quantify the value of some of these secondary factors (such as improved land values surrounding a LID alternative). Typically, however, quantifying environmental benefits (in terms of dollars) to analyze costs and benefits is difficult because few markets are available for obtaining the relevant values. In the next chapter (Table 4-1), we summarize this information on the benefits of LID and provide references. If value data can be applied to secondary benefits, the total should be considered in the decision-making process. The worksheet in Table 3-2 represents a simplified approach to applying the concepts discussed in this report. This approach is designed to set the stage for an extensive, yet practical, analysis for LID projects.
Tool Scope	
Inputs	Costs by project phase
Outputs	
Website	http://lowimpactdevelopment.org/lidphase2/pubs/LMI%20LID%20Report.pdf

6.2 COST SOURCES

6.2 COST SOURCES

	Construction Cost ($)			Maintenance Cost			Lifespan (Years)		
	Low	Mid	High	Low	Mid	High	Short	Mid	Long
Component (Traditional)									
Concrete Sidewalk and Driveway (Sq. Ft)	6	8.5	11						
Concrete Sidewalk and Driveway (Sq. Ft)	5	7.5	10						
Concrete Sidewalk and Driveway (Sq. Ft)	4	6	8	6	8	10	10	20	30
Concrete Sidewalk and Driveway (Sq. Ft)	2.67	3.05	3.51						
Concrete Sidewalk and Driveway (Sq. Ft)		9	10.5						
Average	4.4175	**6.81**	8.602	6	**8**	10	10	**20**	30
Curbs and Gutters	28	30	32						
Curbs and Gutters	15	25	35						
Curbs and Gutters	20	25	30	22	27	32	10	20	30
Curbs and Gutters	15.3	17.2	20.21						
Curbs and Gutters		26.5							
Average	19.575	**24.74**	29.3025	22	**27**	32	10	**20**	30
Street (Sq. Ft)	2	3.25	4.5						
Street (Sq. Ft)	4	6	8	2	3	4	10	20	30
Street (Sq. Ft)	2.6	3.8	4.2						
Street (Sq. Ft)					0.83		20	30	40
Street (Sq. Ft)	5.9	6.05	6.19						
Average	3.625	**4.775**	5.7225	2	**1.915**	4	15	**25**	35
Parking Lot (Sq. Ft)	1.5	2.5	3.5						
Parking Lot (Sq. Ft)	4	6	8	2	3	4	10	20	30
Parking Lot (Sq. Ft)	2.6	3.8	4.2						
Average	2.7	**4.1**	5.233333333	2	**3**	4	10	**20**	30
Conventional Stormwater Storage	4	6	8	5	7	9	10	20	30
Conventional Stormwater Storage							50	62.5	75
Conventional Stormwater Storage		11272							
Corrugated Metal Pipe (CMP)							20	22.5	25
8 in		17.55							

10 in		21.5							
12 in		26							
15 in		30							
18 in		35.5							
24 in		43							
30 in		64.5							
36 in		82							
48 in		116							
60 in		155							
72 in		241							
Reinforced Concrete Pipe (RCP)								70	
12 in		29.5							
15 in		33							
18 in		36							
21 in		43.5							
24 in		50.5							
27 in		69.5							
30 in		74							
36 in		97.5							
42 in		121							
48 in		144							
60 in		216							
72 in		289							
84 in		450							
96 in		550							
Standard Roof									
Composition (Sq. Ft)	1.5	4	6				12	21	30
Metal (Sq. Ft)	5	6	7		1		20	40	60
Slate (Sq. Ft)	30	40	50				40	70	100
Wood (Sq. Ft)	4	5	6				10	20	30
Clay Tile (Sq. Ft)		10	20				20	35	50
Component (LID)									
Green Roof (Sq. Ft)	10	25	35		0.75	1.5	20	25	30
Permeable Pavement - Paving Blocks (Sq. Ft)	17	19.5	22		4.36		25	37.5	50
Permeable Pavement - Porous Asphalt (Sq. Ft)	2	3.75	5.5		4.36				
Permeable Pavement - Porous Concrete (Sq. Ft)	4.5	7.25	10		4.36		20		
Permeable Pavement - Gravel (Sq. Ft)	6	7	8				25	37.5	50
Turf (Artificial) (Sq. Ft)	9	10	11				15	20	25
Turf (Lawn) (Sq. Ft)	0.75	1	1.25				10	15	20

Native Plants (1 gallon/1 Sq. Ft)		8.45							
Bioretention Basin (Sq. Ft)		16.7			0.61			25	
Rain Garden (Sq. ft.)	5	8.05	11.1		0.61			25	
Bioretention Slope (Sq. Ft)		3.3			0.07			25	
Trees (15 gallon tree)	115	132.5	150					15	
Tree Box Filters (one 6' x 6' unit)	6000	7750	9500	75	287.5	500		25	
Bioswales (Sq. Ft)	6.67	11.1	16.7	0.22	0.415	0.61		25	
Grassed water quality Swale (Sq. Ft)		6.7			0.22			25	
Downspout Disconnection		13							
Planter Boxes - Concrete (Sq. Ft)		8			0.8	1.8		25	
Planter Boxes - Wooden (Sq. Ft)		11.1							
Rain Barrels (per 100 gallon reservoir)	245.3	412.65	580		10.38			25	
Rain Harvesting System - Welded Steel Tank		6900						35	
Rain Harvesting System - Poly Tank		3810.4						20	
Vegetated Filter Strips (Sq. Ft)	0.3	0.49	0.68	0.22	0.415	0.61		25	
Amended Soil (Cubic Yd.)	35	42.5	50						
French Drain (Cubic ft.)	10	12.5	15						
Greywater system ($/system or house) low to high end system	700	3000	10000						
Irrigation Controller (includes instillation and wiring)		394					5	10	15
Cultivated flower or vegetable garden	3	6.5	10						
Sparse irrigated vegetation		5					5	10	15
Dense irrigated vegetation		8					5	10	15
Natural/naturalized vegetation (Un-irrigated)		0			0			999	
Pool (Sq. ft.)		50					20	25	
Pond (Sq. ft.)	6	7	8						
Brick (Sq. ft.)	12	18.5	25						

Deck (Sq. ft.)	10	22.5	35				10	15	20
Small Cistern System (100-500 gallons)	250	1000	2500				20	35	50
Large Cistern System (over 1000 gallons)	5000	10000	15000				20	35	50
Open space acquisition ($/acre)	3330	6704.5	10079	25	212.5	400		999	

Sources and Notes:

	Sources	Notes
Component (Traditional)		
Concrete Sidewalk and Driveway (Sq. Ft)	Jim Murphy Associates [6.26.12]	
Concrete Sidewalk and Driveway (Sq. Ft)	Ghilotti Bros [6.27.12]	
Concrete Sidewalk and Driveway (Sq. Ft)	Engineering firm, confidential [7.2.12]	
Concrete Sidewalk and Driveway (Sq. Ft)	Homewyse [6.25.12]	
Concrete Sidewalk and Driveway (Sq. Ft)	Town of Windsor [7.2.12]	
Average		
Curbs and Gutters	Town of Windsor [7.2.12]	
Curbs and Gutters	Ghilotti Bros [6.27.12]	
Curbs and Gutters	Engineering firm, confidential [7.2.12]	
Curbs and Gutters	Homewyse [6.25.12]	
Curbs and Gutters	Rohnert Park Public Facilities Finance Plan [7.6.12]	
Average		
Street (Sq. Ft)	Ghilotti Bros [6.27.12]	
Street (Sq. Ft)	Engineering firm, confidential [7.2.12]	
Street (Sq. Ft)	Town of Windsor [7.2.12]	Asphalt Concrete Type "A"
Street (Sq. Ft)	Patrick Barnes, Rohnert Park [7.6.12]	
Street (Sq. Ft)	Rohnert Park Public Facilities Finance Plan [7.6.12]	Pavement (6"AC/13"AB), Pavement (6"AC/18"AB)
Average		
Parking Lot (Sq. Ft)	Ghilotti Bros [6.27.12]	

Parking Lot (Sq. Ft)	Engineering firm, confidential [7.2.12]	
Parking Lot (Sq. Ft)	Town of Windsor [7.2.12]	Asphalt Concrete Type "A"
Average		
Conventional Stormwater Storage	Engineering firm, confidential [7.2.12]	
Conventional Stormwater Storage	Patrick Barnes, Rohnert Park [7.6.12]	Estimated lifespan for stormwater drains, catch basins are less
Conventional Stormwater Storage	Rohnert Park Public Facilities Finance Plan [7.6.12]	Copeland Creek Stormwater Drainage Ditch. Measured in amount of impervious acres added to Copeland's watershed by new residential development
Corrugated Metal Pipe (CMP)	RS Means, Building Construction Cost Data, 2006	
8 in	RS Means, Building Construction Cost Data, 2006	
10 in	RS Means, Building Construction Cost Data, 2006	
12 in	RS Means, Building Construction Cost Data, 2006	
15 in	RS Means, Building Construction Cost Data, 2006	
18 in	RS Means, Building Construction Cost Data, 2006	
24 in	RS Means, Building Construction Cost Data, 2006	
30 in	RS Means, Building Construction Cost Data, 2006	
36 in	RS Means, Building Construction Cost Data, 2006	
48 in	RS Means, Building Construction Cost Data, 2006	
60 in	RS Means, Building Construction Cost Data, 2006	
72 in	RS Means, Building Construction Cost Data, 2006	
Reinforced Concrete Pipe (RCP)		
12 in	RS Means, Building Construction Cost Data, 2006	
15 in	RS Means, Building Construction Cost Data, 2006	
18 in	RS Means, Building Construction Cost Data, 2006	
21 in	RS Means, Building Construction Cost Data, 2006	
24 in	RS Means, Building Construction Cost Data, 2006	
27 in	RS Means, Building Construction Cost Data, 2006	
30 in	RS Means, Building Construction Cost Data, 2006	
36 in	RS Means, Building Construction Cost Data, 2006	
42 in	RS Means, Building Construction Cost Data, 2006	
48 in	RS Means, Building Construction Cost Data, 2006	
60 in	RS Means, Building Construction Cost Data, 2006	
72 in	RS Means, Building Construction Cost Data, 2006	
84 in	RS Means, Building Construction Cost Data, 2006	
96 in	RS Means, Building Construction Cost Data, 2006	
Standard Roof		
Composition (Sq. Ft)	Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12]	

Metal (Sq. Ft)	Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12], (http://www.homewyse.com/costs/cost_of_metal_roofing.html), (http://www.themetalinitiative.com/content/building_with_metal/benefits/costefficiency/ce_lifecyclecosting_analysis.cfm)	
Slate (Sq. Ft)	Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12]	
Wood (Sq. Ft)	Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12]	
Clay Tile (Sq. Ft)	Dikey Inspection Group [6.27.12], National Roofing Contractors Association [7.11.12]	
Component (LID)		
Green Roof (Sq. Ft)	Bertotti Landscaping, Inc. [7.3.12], (http://www.epa.gov/hiri/mitigation/greenroofs.htm), (http://www.epa.gov/hiri/resources/pdf/GreenRoofsCompendium.pdf) - (pg.10),	Includes basic irrigation.
Permeable Pavement - Paving Blocks (Sq. Ft)	Bertotti Landscaping, Inc. [7.3.12], (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf)	Life expectancy depends on traffic and use on pavers.
Permeable Pavement - Porous Asphalt (Sq. Ft)	Empire Asphalt and Engineering Co. Inc. [7.3.12], (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf)	(Low Cost) Based on estimates of material and installation with a typical 2-inch thickness. (High cost conversion calculation) 1/2 acre=21780 Sq. Ft x .1 (10%)= 2178, $12,000/2178= $5.50/Sq. Ft
Permeable Pavement - Porous Concrete (Sq. Ft)	Empire Asphalt and Engineering Co. Inc. [7.3.12], (http://www.wbdg.org/ccb/AF/AFSUSTTOOLKIT/PolicyLibrary/ufc_3_210_10.pdf)-(pg.53)	Based on estimates of material and installation with a typical 4-inch thickness.
Permeable Pavement - Gravel (Sq. Ft)	Bertotti Landscaping, Inc. [7.3.12]	Life expectancy depends on maintenance and frequency of replenishment of gravel.
Turf (Artificial) (Sq. Ft)	http://winecountrygreens.com/contact-us/	Price reflects material, and installation on a 1200 Sq. Ft area (July 2, 2012)
Turf (Lawn) (Sq. Ft)	Berottti Landscaping, Inc. [7.3.12], http://www.wbdg.org/ccb/AF/AFSUSTTOOLKIT/PolicyLibrary/ufc_3_210_10.pdf	Price reflects material and installation of turf, no irrigation system. Maintenance cost reflects the do it yourself cost of relatively $0 to hiring a gardener for $25/week
Native Plants (1 gallon/1 Sq. Ft)	Details Landscape Art, Contact: Travis Bradley	
Bioretention Basin (Sq.	(http://www.lowimpactdevelopment.org/bigbox/lid%20a	For larger drainage areas than

6.2 COST SOURCES

Ft)	rticles/bigbox_final_doc.pdf)	rain gardens. Useful to be incorporated within impervious areas (parking lots)
Rain Garden (Sq. ft.)	(http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf)	Useful for small drainage areas and within impervious areas. Commercial/industrial rain garden costs are much higher due to additional curbing and filtration construction techniques required in a development
Bioretention Slope (Sq. Ft)	(http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf)	Useful for sloped medians and for edges of elevated impervious areas
Trees (15 gallon tree)	Ron DeNicola, Parks Manager, Arborist, City of Petaluma [7.5.12], Details Landscape Art, Contact: Travis Bradley	Price reflects 15-gallon size tree including installation. Average life expectancy in an urban setting is 15 years.
Tree Box Filters (one 6' x 6' unit)	Details Landscape Art, Contact: Travis Bradley, http://www.wbdg.org/ccb/AF/AFSUSTTOOLKIT/PolicyLibrary/ufc_3_210_10.pdf, http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf	Often, maintenance costs are included by the manufacturer for up to two years after purchase, a $1500 value.
Bioswales (Sq. Ft)	(Lifespan): http://www.deq.state.or.us/wq/stormwater/docs/nwr/biofilters.pdf, (cost estimate): http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf, http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=75&minmeasure=5	Useful along roadsides and other impervious areas such as parking lots.
Grassed water quality Swale (Sq. Ft)	(http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf)	Used for small drainage areas with low water velocities. Usually installed in existing natural low areas to treat stormwater
Downspout Disconnection	http://www.swfwmd.state.fl.us/files/database/social_research/Downspout_Disconnection_Final_Report.pdf	In some cities (Portland, OR) the city actually pays the homeowners either $53 per downspout incentive to do it themselves or have the city provide the service for free. (This price includes disconnecting an existing downspout).
Planter Boxes - Concrete (Sq. Ft)	http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf	Every 5 years the concrete may have to be repaired changing the maintenance cost to increase to $1.8/Sq. Ft
Planter Boxes - Wooden	Details Landscape Art, Contact: Travis Bradley	

(Sq. Ft)		
Rain Barrels (per 100 gallon reservoir)	Details Landscape Art, Contact: Travis Bradley, (lifespan)-(http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf)	This is an average cost. There exists a large variation of rain barrel sizes and material types which all play a role in cost. More specific information at: (http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf)-(pg. 54)
Rain Harvesting System - Welded Steel Tank	Nicole Oblad, Project Manager, National Storage Tank, Inc. [7.6.12]	Standard (common household size) 5000 gallon steel tank w/internal epoxy coating, fittings, pump, hydroscreen, and gravel ring. NOTE: Price reflects material only, delivered but uninstalled.
Rain Harvesting System - Poly Tank	Nicole Oblad, Project Manager, National Storage Tank, Inc. [7.6.12]	Standard (common household size)-5000 gallon poly tank, gravel ring, standard pump, and hydroscreen downspout filter plus tax and freight. NOTE: Price reflects material cost only if picked up from Santa Rosa location, uninstalled.
Vegetated Filter Strips (Sq. Ft)	http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=76, http://www.wbdg.org/ccb/AF/AFSUSTTOOLKIT/PolicyLibrary/ufc_3_210_10.pdf (pg. 45)	
Amended Soil (Cubic Yd.)	Bertotti Landscaping, Inc. [7.3.12]	
French Drain (Cubic ft.)	Details Landscape Art, Contact: Travis Bradley	
Greywater system ($/system or house) low to high end system	Details Landscape Art, Contact: Travis Bradley, http://greywateraction.org/content/cost-greywater-systems	The price range covers the basic cost of a low-tech system to the highest price and complexity system
Irrigation Controller (includes instillation and wiring)	Details Landscape Art, Contact: Travis Bradley	For single-family lot (6000 Sq. Ft) approx. Costs $200-$300 and can be self-installed.
Cultivated flower or vegetable garden	Josiah Cain, Design Ecology	Annual
Sparse irrigated vegetation	Josiah Cain, Design Ecology	Perennials: 10 years
Dense irrigated vegetation	Josiah Cain, Design Ecology	Perennials: 10 years
Natural/naturalized vegetation (Un-irrigated)		Undeveloped, not maintained
Pool (Sq. ft.)	http://www.landscapingnetwork.com/swimming-	

	pool/cost.html	
Pond (Sq. Ft)	http://www.homewyse.com/services/cost_to_dig_pond.html, Details Landscape Art, Contact: Travis Bradley	Average pond of 1000 Sq. Ft
Brick (Sq. ft.)	http://www.landscapingnetwork.com/patios/brick.html, http://www.homewyse.com/costs/cost_of_brick_patio.html	
Deck (Sq. ft.)	http://home.costhelper.com/deck.html	
Small Cistern System (100-500 gallons)	Lifespan data: (http://www.portlandoregon.gov/bes/article/127468)	
Large Cistern System (over 1000 gallons)	(http://home.costhelper.com/cistern.html), (http://www.lid-stormwater.net/raincist_cost.htm), lifespan data: (http://www.portlandoregon.gov/bes/article/127468)	
Open space acquisition ($/acre)	Acre cost: (http://www.sonomafb.org/Farm+News/Farm+News+Archive/2012/Jun+12/Land+Conservation+At+What+Cost.htm) Maintenance cost: (http://www.watchsonomacounty.com/2012/11/county/sonoma-county-votes-to-accelerate-transfers-of-open-space-land-to-other-agencies/)	Price varies significantly on factors that dictate the value of land. This value is a Sonoma County average cost per acre.

6.3 TABLE OF STORMWATER POLICIES

	Traditional (1977)	SUSMP (2005)	GreenPoint (2005)	One Planet (2010)
SUSMP				
Source Controls				
Downspouts- Drain to Landscaping	•	•		
Benign Roof Materials (e.g. Tile)				
Roof Gardens				•
Cluster Unit Development		•		
Multi-Story Buildings		•	•	•
Avoid Exposing Bare Earth (e.g. Bark, Mulch, Gravel)		•	•	•
Vegetated Strips	•	•	•	•
Hollywood Driveways		•		
Minimize Directly: Connected Impervious Areas		•	•	•
Flow Through Landscaped Area Before Going to Storm Drain		•	•	•
Label Inlets: "No Dumping-Drains to Creek"		•	•	
Spray Irrigation		•	•	
Targeted Spray Irrigation				•
Drip Irrigation		•	•	•
Bubblers				•
Subsurface Irrigation				•
Plants Maintained through Minimal Water Use		•	•	•
Naturally Treat Storm water		•	•	•
Avoidance of Natural Areas (e.g. wetlands)		•	•	•
Naturally Vegetated Setback	•		•	•
Buildings Away from Natural Areas		•	•	•

	Traditional (1977)	SUSMP (2005)	GreenPoint (2005)	One Planet (2010)
Treatment Controls				
Vegetated Swale			•	•
Bioretention Area	•		•	•
Extended Detention Basin			•	•
Vegetated Buffer Strips	•	•	•	•
Constructed Wetlands			•	
Wet Pond				
Media Filter				
Manufactured Media Filter				
Infiltration Basin				•
Manufactured Vortex Separator			•	
Manufactured Drain Inserts		•		
CALGREEN				
Rain Barrels				•
Permeable Pavers (No less than 20%)				•
Shade Trees			•	•
Limit Turf (Not more than 50%)			•	•
75% Native California/ Drought Resistant Plants			•	•
Hydro-zone Irrigation Techniques			•	•
Automatic Irrigation Controllers			•	•
Rainwater Capture System				•
Landscape Irrigation Design Reduces use of Potable Water				•
LEED				•
One Planet				•

6.4 CALCULATIONS

➤ **LOT**

Total Impervious Surfaces

Water Runoff

Outdoor Water Consumption

GHG Output

➤ **NEIGHBORHOOD**

Total Impervious Surfaces

Water Runoff

Outdoor Water Consumption

GHG Output

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